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PROCEEDINGS

OF THE

AMERICAN ACADEMY

OF

ARTS AND SCIENCES.

VOL. XX.

PAPERS READ BEFORE THE ACADEMY.

I.

A REVISION OF THE NORTH AMERICAN SPECIES OF THE GENUS OXYTROPIS, DC.

By Asa Gray.

Communicated May 14th, 1884.

In the sixth volume of the Proceedings of the American Academy (1863), as an appendix to a revision of *Astragalus*, I made an attempt to classify and characterize our comparatively few species of *Oxytropis*. In the autumn of 1880, I compared our own materials with those in the Kew herbarium, but, unfortunately, without knowing of Bunge's *Species Generis Oxytropis*, which was communicated to the Imperial Academy of Sciences of St. Petersburg in November, 1873, and published in its *Mémoires*, Ser. VII. Vol. XXII., in 1874. Bunge cites my notes, but he had not the means for clearing up the obscurities. Even now, after some examination of most of the originals, I can only partially remove them. But the subjoined synopsis may fairly represent our present knowledge.

OXYTROPIS, DC.

§ 1. Caulescens, nunc subcaulescens; stipulis inter se et a petiolo liberis: legumen uniloculare calycem longe superans. — Subgen. *Phacoxytropis* § *Mesogææ*, Bunge.

1. O. deflexa, DC. *O. foliolosa*, Hook. (*O. foliosa*, in Torr. & Gray, Fl.), forma subacaulis. — Saskatchewan, and along the Rocky Mountains to S. Colorado. (N. Asia.)

§ 2. Acaulescens vel subcaulescens; caudicibus multicipitibus conferte foliosis, stipulis petiolo adnatis: folia simpliciter pinnata.

* Legumen calyce fructifero ovato-globoso vesicario prorsus inclusum, ovatum, uniloculare: pedunculi debiles 1–2-flori. — § *Physocalyx*, Nutt. § *Calycophysæ*, Gray, Proc. Am. Acad. vi. 234. Subgen. *Physoxytropis*, Bunge, Oxytr. 161.

2. O. MULTICEPS, Nutt. in Torr. & Gray, Fl. i. 341. — Rocky Mountains of Wyoming, *Nuttall*, in fruit only.

Var. MINOR. Pulvinato-cæspitosa, depressa; foliolis minoribus lin. 1–3 longis. — *O. multiceps*, Gray, Proc. Acad. Philad., 1863, 61; Proc. Am. Acad. vi. 234. — Alpine region of the Rocky Mountains, S. Wyoming and Colorado, *Parry*, *Hall & Harbour*, *Vasey*, *Coulter*, &c. Leaflets about half the size of those of Nuttall's original, and fruiting calyx rather smaller. No quite intermediate specimens have yet been found.

* * Legumen calyce fructifero repleto vel hinc fisso parum longius, turgidum, pubescens, sutura ventrali introflexa semi-bilocellatum: scapi folia superantes, capitato-pluri- vel pauci-flori: plantæ albo-sericeæ, spithamææ: flores ultra semipollicares, bracteis majusculis.

3. O. NANA, Nutt. l. c. Pube adpressa argenteo-sericea; foliolis 3–4-rarius 6-jugis angusto-lanceolatis; corolla purpurea vel pallida; legumine turgido-oblongo subcoriaceo, apice acuminato e calyce fructifero tenuiter villoso distento sed integro parum exserto. — Rocky Mountains of Wyoming, on stony hills along the branches of the Platte, *Nuttall*, *Geyer*, the latter under the name of *O. multiceps* in Hook. Lond. Jour. Bot. N. W. Wyoming, *Parry*, no. 91 & 90, along with a larger form, with the inflorescence in fruit sometimes oblong; the same collected by *Dr. Forwood.* S. Montana, *S. Watson*, who notes that the flowers are "deep pink." This may be *O. argentata* of Pursh. Fl. 473.

4. O. LAGOPUS, Nutt., Jour. Acad. Philad. vii. 17. Pilis laxioribus albo-sericea; foliolis 4–5-jugis lanceolatis vel oblongis; corolla læte violacea; legumine ovato subvesicario fere membranaceo obtuso stylo subito rostrato calycem villosissimum mox fissum parum superante. — Rocky Mountains of Wyoming and Montana, *Wyeth*, *Howard*, *Parry* (no. 92), *Greene*, *Scribner*.

* * * Legumen basi tantum calyce aut integro aut hinc fisso suffultum,

+ Vesicario-inflatum membranaceum, ovatum, uniloculare: scapi vel pedunculi debiles, pauciflori, fructiferi mox decumbentes: herbæ

nanæ, cæspitoso-depressæ. — § *Physocarpæ*, Gray, Proc. Am. Acad. vi. 234.

5. O. PODOCARPA, Gray, l. c. Villosa, mox glabrescens; foliolis 5–11-jugis lineari-lanceolatis (lin. 3–4-longis); pedunculis folia haud superantibus bifloris; floribus majusculis (lin. 7–8 longis); corolla violacea; legumine amplo (sæpius pollicem longo) lato-ovato puberulo brevi-stipitato, sutura ventrali intrusa. — *O. arctica*, var. *inflata*, Hook. Fl. Bor.-Am. i. 146. *O. Hallii*, Bunge, Oxytr. 162, described from a specimen barely in flower, appears to be of this species. — Alpine and subalpine in the Rocky Mountains, from S. Colorado (*J. M. Coulter*, *Greene*, *Brandegee*, *Hall & Harbour*, &c.) to British America (*Drummond*, *Burke*, *Bourgeau*, *Macoun*); and from Labrador to the Aleutian Islands; but specimens from the latter not in fruit, therefore uncertain. The stipe of the legume is variable, sometimes very short, perhaps never quite equalling the calyx.

6. O. OREOPHILA. Sericeo-canescens; foliolis 3–5-jugis lanceolatis oblongisve (lin. 2–4 longis); scapis folia plerumque superantibus capitato-4–8-floris; floribus parvulis (lin. 4–5-longis); corolla ut videtur purpurea; legumine haud stipitato oblongo-ovato griseo-pubescente vix semipollicari, sutura ventrali subintrusa. — Mountains of Utah (Aquarius Plateau at nearly 10,000 feet, *L. F. Ward*, in 1875), and on Grayback Mountain, San Bernardino Co., S. California, at 9,000–12,000 feet, *W. G. Wright*, *Lemmon*, in 1879–80.

A possible variety of this, or a related species, with flowers almost immersed in the tufts of foliage, was collected in Rabbit Valley, Utah, by Mr. Ward (no. 574), but only in blossom.

+ + Legumen obcompressum, lanceolato-oblongum, tenui-chartaceum, sæpius nigricanti-pilosum, suturis utrisque intrusis fere bilocellatum: pedunculi 1–2- (raro 3-) flori, breves vel brevissimi in caudicibus nanis foliosissimis.

7. O. NIGRESCENS, Fischer in DC. Prodr. ii. 278. *Astragalus nigrescens* (large form) & *A. pygmæus*, Pall. Astrag. t. 53, 54. — Arctic coast, especially on the Asiatic side; coll. by *C. Wright* on Arakamtschetchene Island within Behring Strait; and by *J. Muir* on Cape Thompson, on the American side.

Var. ARCTOBIA. Pumila, pulvinato-depressa, albo-villosa; pedunculis unifloris; pube calycis et leguminis aut griseo-albida aut nigra. — *O. arctica*, var., R. Br. in Parry, Voy. *O. arctica*, var. minor, Hook. in Parry, 2d Voy. 396, & Fl. Bor.-Am. i. 146. *O. arctobia*, Bunge, Oxytr. 114, excl. syn. Nutt. — Arctic sea-coast, coll. Admiral Parry and most later explorers. Evidently passes into *O. nigrescens*.

+ + Legumen fere teres, turgidum, sæpius hinc sulcatum, chartaceum vel coriaceum: scapi sat elongati, 1–4-flori.

= Foliola plurijuga: legumen angusto-oblongum, haud stipitatum, septo e sutura ventrali introflexo bilocellatum.

8. O. PARRYI. Sericeo-canescens; foliis scapisque 1–2-floris demum spithamæis; foliolis 7–9-jugis oblongo-lanceolatis lin. 2–3 longis; calyce brevi griseo-pubescente, dentibus tubo campanulato æquilongo: legumine (lin. 5–6 longo) hinc profunde sulcato pube brevi griseo. — Rocky Mountains of Northern New Mexico and Colorado, near the limit of trees, *Parry*, *Hall & Harbour*, *Greene*, with mature fruit in July: flowers not seen. Was named by me *O. arctica* in Hall & Harbour's collection, no. 143, and *O. Uralensis*, var. *pumila*, in Proc. Am. Acad. vi. 235, and *O. Lagopus*, Nutt., was wrongly referred to it. From the references this would seem to be the plant described as *O. arctica* by Bunge, Oxytr. 97, but his character does not accord with Hall & Harbour's specimens, which want the flowers, and are very different from Brown's plant (which I now know). It would seem that Bunge's description was drawn partly from Hall & Harbour's specimens, partly from Brown's character of *O. arctica*, and partly from that of *O. Lagopus*, Nutt., which I had very wrongly adduced to Brown's species.

= = Foliola 4–6-juga, villoso-sericea: legumen ovato-oblongum, haud stipitatum, semibilocellatum, cum calyce sæpius nigricanti-pubescens: scapi folia superantes, capitato-2–5-flori.

9. O. ARCTICA, R. Br. App. Parry Voy. 278 (non 309); Hook. Fl. Bor.-Am. l. c., excl. β & δ. *O. Uralensis*, var. *arctica*, Ledeb. Fl. Ross. i. 594. Probably also *O. Uralensis*, var. *pumila*, Ledeb. l. c. — Arctic sea-coast, coll. first in Admiral Parry's voyage, also by Richardson and by later arctic explorers. Certainly not a form of *O. Uralensis;* the stipules destitute of the nervation of that species, having only a midnerve and one or two recurving veins. Plant quite unlike the forms of *O. nigrescens* and *O. podocarpa*, which have been referred to it.

= = = Foliola aut 3–5, aut solitaria; legumen oblongo-ovatum, brevi-stipitatum, nigricanti-pubescens, sutura ventrali intrusa vix semi-bilocellatum: scapi folia superantes, 1–4-flori.

10. O. MERTENSIANA, Turcz., Ledeb., Bunge, Oxytr. 116. — I have fruiting specimens of this from Arakamtschetchene Island, on the Asiatic side, within Behring Strait, collected by *C. Wright*. From my notes made in the Kew herbarium, I am disposed to consign to it, rather than to *O. arctica*, the specimens referred to the latter species by Seemann

(Bot. Herald, 28), collected by him at Cape Lisburne, on the American side, in flower only. Captain Pullen's plant, collected west of Cape Bathurst, seemed to be the true *O. arctica*, R. Br.

+ + + + Legumen fere teres, turgidum, hinc vel utrinque sulcatum, chartaceum vel coriaceum: scapi capitato- vel spicato-pluriflori, folia plurifoliolata æquantes vel superantes: stipulæ in nostris uninerviæ, rarius apice acuminato subtrinerviæ. Species perdifficiles.

++ Aut pube villosa aut glandulis sessilibus pl. m. viscosa, saltem calyces: foliola vel glabella vel villosa mox glabrata, viridia, nunquam sericea: legumen oblongum, haud stipitatum, tenui-chartaceum, sutura ventrali introflexa semi- vel sub-bilocellatum.

11. O. VISCIDA, Nutt. in Torr. & Gray, Fl. i. 341. Floribus in capitulum oblongum demumve spicam tripollicarem congestis; calyce brevi-campanulato piliis albidis vel griseis villoso; legumine parvulo (lin. 3–5 longo) tantum puberulo stylo recto tenui-rostrato. — Rocky Mountains, from the British Possessions to Colorado and N. Nevada; common in Wyoming. The small projecting glands which give the viscidity are sometimes conspicuous on petioles, scapes, bracts, and calyx, and even on the legume, but in many dried specimens they are hardly to be detected. Flowers about 5 lines long: corolla probably not ochroleucous, sometimes apparently white with either the tip of the keel or lamina of wings and standard violet. The species is well represented by no. 89 of Parry's N. W. Wyoming collection; also by his no. 88, in flower only, and by no. 292 of Watson's collection in King's Exploration. Northward it was collected by Bourgeau (distrib, as *O. campestris?*), and by Macoun, at Bow River Pass.

12. O. LEUCANTHA, Pers. Syn. ii. 331; Bunge, Oxytr. 111. *O. borealis*, & *O. leucantha*, DC. Capitulo etiam fructifero brevi parum oblongo; calyce oblongo-campanulato pilis nigris albidisque villoso; legumine ventricoso ¾-pollicari nigricanti-villoso stylo mox recurvato rostrato. — Specimens of this from C. Wright's collection on Arakamtschetchene Island, on the Asiatic side of Behring Strait, have been so named by Bunge, and they accord with the figure of *Astragalus leucanthus* in Pall. Astrag. t. 47. Not a good name, the corollas being, as in the figure, well suffused with violet. Stouter forms of it were collected by Seemann on the American side, perhaps white-flowered; and a form with white-haired calyx was collected at Cape Thompson, &c. by Muir. A part of *O. campestris* of Hook. Fl. Bor.-Am. must also be of this species. Although placed among the glandular-viscid species by Bunge, the glandulosity is obscure, and in some specimens not apparent. Occasionally the long hairs of the calyx seem to be viscous.

++ ++ Nec glandulosa nec viscida: legumen haud vel vix stipitatum.

13. O. CAMPESTRIS, L., var. CÆRULEA, Koch. Sæpius nana; foliolis viridibus, maturis laxe pubescentibus vel glabratis parvulis (lin. 3–4 rarius 5–6 longis); floribus etiam fructibus capitato-congestis raro in spica laxiuscula parum dissitis; corolla cærulea albo-cærulea nunc plane alba semipollicari; legumine semipollicari membranaceo-chartaceo turgide ovato seu oblongo semi- vel sub-bilocellato nigricanti-puberulo. — Northern Maine, Lower Canada, (near Quebec, &c.), and Labrador. These are the only American stations I can cite for *O. campestris*, taking that species to comprise *O. sordida.* And as our specimens have clear violet or blue corollas, when not pure white (as some few are completely), I adopt Koch's name given to the quite similar form in Europe. The stipules are either simply one-nerved, or some with a triple nerve at the apex, differing in this particular in the same plant. A slight introflexion of the dorsal suture is apparent in the legumes of the South Labrador specimens collected by Dr. Allen.

14. O. MONTICOLA. Laxe villoso-sericea, nunc subglabrata, spithamæa ad pedalem; foliolis oblongis vel lanceolatis (lin. 3–7 longis); spica oblonga vel cylindracea etiam fructifera conferta; corolla aut violaceo-purpurea aut ochroleuca vix semipollicari; legumine ovato-oblongo recte acuminato membranaceo-chartaceo lin. 4–6 longo aut prorsus uniloculari aut sutura ventrali introflexa semibiloculari pube brevi albido-sericeo calycem campanulatum vix ultra dimidium superante. — Northern Rocky Mountains; viz. Wyoming and Montana, *Parry*, no. 87, *Canby;* Dakota, coll. *Jenney*, but in flower only. Rocky Mountains in British Possessions, *Bourgeau*, with fruit, *Lyall*, in flower only; and Spy Hill, *Macoun*, 1879, no. 107, in fruit. Probably some of this species is included in *O. campestris* of Hook. Fl. Bor.-Am.; but his var. *spicata* seems rather to belong to *O. Lamberti.* It is more like *O. viscida*, Nutt., but is neither glandular nor viscid. Here may belong a plant collected by *Dall* on a rocky talus in front of a glacier at Chugachik Bay, Cook's Inlet, Alaska, in flower only.

15. O. LAMBERTI, Pursh. Spithamæa ad sesquipedalem, pube adpressa sæpius albida vel argentea sericea, quandoque glabrata; foliolis oblongo-lanceolatis linearibusque lin. 4–16 longis; spica aut brevi-oblonga densiflora aut elongata demum sparsiflora; floribus sat magnis (majoribus pollicaribus) læte violaceis vel purpureis vel albis etiam sulphureis; legumine coriaceo oblongo sub-bilocellato sericeo-puberulo (stipite aut plane nullo aut brevissimo) nunc semipollicari turgido calycem haud ultra dimidium superante nunc subpollicari magis ex-

serto. — Sims, Bot. Mag. t. 2148; Lindl. Bot. Rgs. t. 1054; both good figures. *O. Lamberti, sericea, Plattensis, & Hookeriana*, Nutt. in Torr. & Gray, Fl. i. 339, 340. — Plains of the Saskatchewan and Minnesota to W. Texas and New Mexico, west to Montana, British Columbia, Utah, &c. The yellowish-flowered and the purple or violet forms often growing side by side.

Var. SERICEA (*O. sericea*, Nutt. in Torr. & Gray, l. c.) is sometimes well marked, as a robust form, with broader leaflets (from lanceolate to oblong, and 3 or 4 lines wide), and cylindraceous legumes nearly or quite an inch long; the pubescence of the leaflets very silky: but these characters very variable. It abounds from the mountains of Wyoming to those of Texas and Arizona, and to the eastern borders of California. A form with slender legumes passes into

Var. BIGELOVII. Legumes distinctly stipitate in the calyx, slender (an inch long, including the style, only 2 lines in diameter), minutely puberulent under a lens, very thin-coriaceous: leaves narrow, green and glabrate. — *O. Lamberti*, Torr. in Pacif. R. Rep. iv. 80. — On the Upper Canadian River, in Colorado? *Bigelow*.

§ 3. Acaulescens; stipulis petiolo adnatis; scapis spicigeris: folia verticillato-pinnata, nempe foliolis pluribus quasi in fasciculis seu verticillis ordinatis. — § *Verticillares*, DC.

16. O. SPLENDENS, Dougl. in Hook. Fl. Bor.-Am. i. 147, cum var. *vestita* & var. *Richardsonii* (*O. oxyphylla*, Richards. non Pall.). Nitenti- (sæpius argenteo-) sericeo-villosa: legumine ovato sutura dorsali parum ventrali longe introflexa bilocellato calyce villosissimo longe angusteque 5-dentato demum hinc fisso fere incluso. — Subarctic British America to the Rocky Mountains, from Montana to Colorado and northern part of New Mexico. The specimens of Richardson, in which, according to Sir William Hooker, the fruit greatly exceeds the calyx in length, should be re-examined. In all ours the legume is as described above: and the beak of the keel is not so very short as Bunge describes it.

II.

NOTES ON SOME NORTH AMERICAN SPECIES OF SAXIFRAGA.

By Asa Gray.

Communicated June 11th, 1884.

Saxifraga peltata, Torr. Peltiphyllum, Engler, is an appropriate name for this very distinct section, which certainly connects *Bergenia* of Mœnch with the true Saxifrages. Apart from the very thick and much-creeping rhizome, which is that of *Bergenia* exaggerated, and the huge peltate leaves, which are peculiar, the section is marked by its roundish and rotately spreading and promptly *deciduous* petals, reflexed calyx, and comparatively large (a line long) and loose-coated seeds. As to the distinction made by Engler, that the flowers of *Bergenia* are protogynous and those of *Saxifraga* protandrous, I remark that, while most plants of *S. peltata* are protandrous, some of our native specimens are either truly protogynous in the sense that their anthers are later than the stigmas, or their stamens are reduced in size and probably in efficiency, that is, the flowers show a tendency to be gyno-diœcious. Engler's mistake in placing his section *Peltiphyllum* under a division with capsule dehiscent only at the upper part, has been corrected in the Botanical Magazine and in the Botany of California. His "rhizoma crassiusculum" is not much improved by "rootstock as thick as the thumb" in the Botanical Magazine. Even in cultivation, with us it attains the diameter of "from two to three inches." The divisions of the calyx are neither erect, nor shorter than the tube, but reflexed in anthesis and very much longer than the tube, if tube the consolidated base can be called. Bentham described the petals as marcescent, and Torrey as persistent; but in fact they are early deciduous. The absence of bracts was noted by Bentham, and is used as a sectional character by Engler. But bracts subtending the branches of the panicle do occasionally occur, just as they do in the section *Bergenia*. The carpels in our cultivated plant are turgid in fruit, just as in Dr. Torrey's figure, but commonly more elongated.

Saxifraga ranunculifolia, Hook. We now know this species, it having been rediscovered by Dr. Macoun in the Yale Mountains on Frazer River in British Columbia, in 1875, on the south side of Mount Paddo (Adams), Washington Territory, by Mr. Howell in 1882, and even on Spanish Peak of the Sierra Nevada in California, in 1878, by Mrs. Austin. As it multiplies by granular bulblets in the axils of the radical leaves, and is in other respects congruous with the section *Nephrophyllum*, it ought to be referred to that group, notwithstanding its complete anomaly in having pentandrous flowers; and the section *Isomeria* should be abolished. That was an incongruous assemblage of the Saxifrage now under consideration with two species of *Boykinia* and the *Sullivantia* (genera which may be maintained), along with the decandrous *S. Jamesii*, Torr. (not "Jamesiana"), the proper place of which in the genus is still to seek.

Of the species which in Dr. Engler's monograph are brought together in his section *Boraphila* the following may here be noted.

Saxifraga Tolmæi, Torr. & Gray, is not particularly related to any of the species with which it is associated in Engler's monograph.

Saxifraga stellaris, L., and S. leucanthemifolia, Michx., species with lanceolate, acute, unguiculate, and mostly unequal petals, are of uncertain limitation as respects the forms in N. W. America. The true *S. leucanthemifolia* of the Alleghany Mountains seems thoroughly well-marked, and has no tendency to bear propagating bulblets in the inflorescence. More probably the var. *Brunoniana* of Bongard and Engler belongs to *S. stellaris*. Engler's var. *integrifolia*, of California, is certainly

Saxifraga bryophora, Gray, Proc. Am. Acad. vi. 533 (1863), and a distinct species, nearer to *S. stellaris*.

The remaining species, with obtuse as well as equal petals, so far as they are North American, may be discriminated by means of the following key. The series ends with a peculiar California species, recently discovered, which may be appended to this group.

1. No creeping rootstocks, not bulbilliferous, no cordate or naked-petioled leaves: scape and leaves from a short caudex.

Inflorescence an interrupted spiciform thyrsus, with conspicuous leafy bracts. *S. hieracifolia.*

Inflorescence narrowly thyrsiform or reduced to capituliform, not foliaceous-bracteate: flowers clustered, sessile or short-pedicelled.

Low: leaves mostly dentate: calyx-lobes barely spreading. *S. nivalis.*

Taller: leaves entire or denticulate: calyx lobes reflexed in fruit, broad,

Shorter than the conspicuous petals. *S. integrifolia.*

About equalling the inconspicuous petals. *S. Pennsylvanica.*

Inflorescence effusely elongated-paniculate: small flowers slender-pedicelled: scapes 2 or 3 feet high, the branches commonly subtended by leafy bracts: calyx reflexed: leaves ample, thin,

Denticulate; oval to elongated oblong, 4 to 8 inches long: filaments filiform. *S. Forbesii.*

Acutely and unequally dentate, oblong-lingulate, often a foot long: filaments clavate-dilated. *S. erosa.*

Inflorescence corymbiform- or paniculate-cymose, open when evolute: plants mostly low and scape naked: leaves thickish, short and broad, not distinctly cuneate-attenuate at base, either dentate or only repand.

Calyx erect or barely spreading after anthesis: pedicels of the dichotomal and pseudo-lateral flowers short, mostly shorter than the calyx: filaments filiform-subulate.

Petals pale rose-color. *S. eriophora.*

Petals white. *S. Virginiensis.*

Calyx reflexed in or after anthesis, almost free: pedicels all slender and longer than calyx: filaments disposed to be upwardly dilated, sometimes conspicuously so. *S. reflexa.*

2. Rhizomatose, the rootstock herbaceous and commonly slender: plants not bulbilliferous.

Leaves roundish or oval, dentate, mostly abruptly (truncately or even subcordately) contracted into margined petioles: flowers small and numerous in an effuse compound panicle; its branches and pedicels divergent: petals more or less bimaculate.

Calyx barely spreading: filaments filiform. *S. Careyana.*

Calyx reflexed: filaments clavately dilated. *S. Caroliniana.*

Leaves cuneate and attenuate into margined petioles or contracted base, above incisely dentate.

Calyx erect or barely spreading: filaments slender: flowers small and numerous: leaves flabelliform-cuneate. *S. Dahurica.*

Calyx reflexed: capsule often 3-5-carpellary.

Filaments slender: capsule short and turgid: styles hardly any: flowers comparatively large and few, short-pedicelled: leaves cuneate and short-petioled. *S. Unalaschensis.*

Filaments, or some of them, dilated upward: capsule narrower and longer, more styliferous: leaves more narrowly cuneate and more petiolate. *S. Lyalli.*

Leaves mostly round-reniform, coarsely dentate, on long and naked or barely margined petioles,

Small, usually rather flabelliform than reniform, 3–9-lobulate: petioles, scape (a span high, with few flowers in a loose corymbiform cyme), and rootstocks filiform: calyx erect: filaments filiform. *S. nudicaulis.*

Larger, 7–27-lobulate-dentate: scape a span to a foot high: inflorescence thyrsoidly paniculate or in dwarf forms condensed: creeping rootstock thicker: calyx reflexed in fruit: filaments mostly dilated upward. *S. punctata.*

3. Not rhizomatose, but a scaly-bulbous crown, formed of the dilated-scarious bases of the long petioles, and producing fleshy bulblets in their axils: inflorescence also bulbilliferous: leaves and flowers nearly of the last preceding species. *S. Mertensiana.*

4. Ligneous-rhizomatose and cæspitose: leaves cuneate, lineate-veined, and rounded summit coarsely dentate, on slender wholly naked petioles of the length of the blade: inflorescence narrowly paniculate: calyx-lobes reflexed: filaments slender: seeds cylindraceous. *S. fragarioides.*

Saxifraga hieracifolia, Waldst. & Kit., we have on this continent only on the Arctic coast.

Saxifraga Forbesii, Vasey, in the American Entomologist and Botanist (St. Louis, 1870), p. 288, is a quite distinct and local species, found only on shaded cliffs near Makanda in Southern Illinois, by Mr. S. A. Forbes. The founder compares it with *S. Virginiensis*, which grows also upon rocks; but it is more like *S. erosa*, which grows in and along mountain brooks.

Saxifraga eriophora, S. Watson, Proc. Am. Acad. xvii. 372, is described from specimens collected in the Santa Catalina Mountains of Arizona, in the year 1881, by Mr. and Mrs. Lemmon. It is nearest to *S. Virginiensis;* and the woolliness on the leaves, which suggested the name, hardly appears upon one of the two specimens.

Saxifraga Virginiensis, Michx. (which Linnæus confounded with *S. nivalis*), is now better known and defined, the high northern and far western species which has been confounded with it being discriminated from it. *S. Texana*, Buckley in Proc. Acad. Philad., 1861, 455, can only be referred to *S. Virginiensis*, nothing in the character excluding it, and apparently no specimen is extant.

Saxifraga reflexa, Hook, Fl. Bor.-Am. i. 249, t. 85. This is now substantially identified, and may be distinguished from *S. Virginiensis* by the characters assigned in the above synoptical view; viz. the slender pedicels, reflexed calyx, and the commonly dilated or clavate filaments. The original is Arctic American, but it occurs in the northern part of the Rocky Mountains, thence to British Columbia, and southward along the Cascades and Sierra Nevada, throughout California even to its southern borders, where it has been confounded with *S. Virginiensis.* Mr. Muir collected it in Arctic Alaska; and in Eastern Asia it is well represented by *S. Sachalinensis*, Fr. Schmidt, Fl. Sachal. 133, which answers to Hooker's figure, while *S. Tilingiana*, Regel, Fl. Ajan. 94, appears to be a form with more petiolate and less dentate leaves, which may be matched by Californian specimens.

Saxifraga Dahurica, Pall. (retaining Pallas's orthography), now that we rightly identify it, cannot claim a place in the N. American flora; but it may be expected in Arctic Alaska, for Charles Wright collected specimens of it (along with some of *S. Lyalli*) on an island upon the Asiatic side within Behring Strait. We have it from Ajan in Tiling's collection.

Saxifraga Unalaschensis, Sternb. Saxifr. Suppl. ii. 9, which Engler appends to *S. Dahurica*, is an Aleutian and Arctic Alaskan species, recently collected by Dall and by Muir, also by Dr. Steineger at Copper Island on the Asiatic side. It must also be *S. flabellifolia*, R. Brown in Torr. & Gray, Fl. i. 569.

Saxifraga Lyalli, Engler, Monogr. Saxifr. 141, a well-marked species, of the northern Rocky Mountains, found also by C. Wright on the Asiatic side of Behring Strait.

Saxifraga nudicaulis, Don, Monogr. Saxifr. 366. This is *S. neglecta*, Bray in Sternb. Saxifr. Suppl. i. 9, ii. 36, as well as *S. vaginalis*, Turcz. in Ledeb. Fl. Ross. ii. 220. Don's plant was collected by Nelson, probably in Arctic Alaska (as the name is now used), and Menzies collected it in the same region. Our specimens (coll. Dall and C. Wright) are from the Asiatic shore and islands, and from Ajan, by Tiling. Don's name and that in Sternberg were published in the same year (1822); but, as Don's memoir was "Read, Feb. 20, 1821," we may perhaps assume some priority in publication.

Saxifraga punctata, L. (with synonymy as detailed by Engler), is an unmistakable species. But it passes by many gradations into

Var. nana, an Arctic form, also high alpine in the more northern Rocky Mountains, with scape barely a span high, bearing a simple and small cyme or a close glomerule of few flowers, the leaves much reduced in size and only 7–11-lobulate. This abounds on the coast of Arctic Alaska, within Behring Strait, and answers to *S. Nelsoniana*, Don, only more dwarfed, and the inflorescence condensed; so that no one would refer it to *S. punctata*, except for the intermediate forms. Burke collected a similar form on the higher Rocky Mountains.

Var. acutidentata, Engler, is founded on a plant of Lyall's collection from "Cascade Mountains, South Clear Creek." A specimen in our herbarium which agrees with the character is ticketed "Rocky Mountains, lat. 49°, at 6,500 feet alt." It is a large form, with the slightly cordate base of the leaves abruptly decurrent into a partly winged petiole, the numerous teeth unusually coarse and acute: and some smaller leaves from the rootstock are cuneate.

Saxifraga fragarioides, Greene in Bull. Torr. Club. viii. 121 (1881), a most peculiar species, is one of Mr. Pringle's discoveries, in the northern part of California, on a high mountain west of Mt. Shasta. "The leaves," as Mr. Greene states, "are a most precise imitation of the leaflets of the common Wild Strawberry, both as regards their form, color, texture, and even size." The scape is foliose-bracteate, and the lignescent tufted rootstocks are peculiar.

III.

A CONTRIBUTION TO OUR KNOWLEDGE OF PALEOZOIC ARACHNIDA.

By Samuel H. Scudder.

Communicated June 11th, 1884.

Until a very recent period discoveries of fossil Arachnida in the older rocks had been exceedingly few, and the first and only attempt to show their relations to each other and to living forms was made in a recent paper by Karsch,* occasioned by his description of a new generic type. Yet the first discovery of carboniferous forms dates back to Corda, who described † a scorpion found by Sternberg at Chomle in Bohemia, a discovery which justly awakened at the time the widest interest.

Karsch, in his brief attempt to bring into connected order the discoveries of the past, has established for the bulk of the species which do not belong to the scorpions the order Anthracomarti, divided into two families, the Architarboidæ and Eophrynoidæ.

The following is a succinct account of his arrangement: —

Order 1. ARANEÆ.

Body composed of two principal masses, of which the front (cephalothorax) is unsegmented, and the hinder (abdomen), unsegmented beneath, has at the most a single segmented dorsal plate.

Fam. LIPHISTIOIDÆ Thor.

Abdomen with segmented dorsum.

Protolycosa anthracophila Roemer (Silesia).

Order 2. OPILIONES.

Body forming either a single mass or two segment-complexes, always separated into segments both above and below.

* Zeitschr. deutsch. geol. Gesellsch., 1882, p. 556.

† Verhandl. Gesellsch. vaterl. Mus. Böhmen, 1835, p. 35.

Fam. TROGULOIDÆ.

Dorsal segments of the abdomen each with three transverse fields. Palpi and mandibles not visible from above.

Kreischeria Wiedei Geinitz (Saxony).

Order 3. ANTHRACOMARTI Karsch.

Body composed of two main divisions, of which the front one is unsegmented, the hinder segmented. Palpi visible from above.

Fam. ARCHITARBOIDÆ Karsch.

Number of abdominal segments equal above and below. Integument smooth.

Architarbus Scudder.

Cephalothorax and abdomen not separated by a lateral constriction.

A. rotundatus Scudder (Illinois), *A. subovalis* Woodward (England), *A. silesiacus* Roemer (Silesia).

Anthracomartus Karsch.

Cephalothorax and abdomen distinctly separated by a lateral constriction.

A. Völkelianus Karsch (Silesia).

Fam. EOPHRYNOIDÆ Karsch.

Number of dorsal and ventral segments of the abdomen unequal, more numerous above. Integument tuberculate.

Eophrynus Prestvicii (Buckl.) Woodward (England).

Order 4. SCORPIONES.

Body separated into three main divisions, the cephalothorax unsegmented, the abdomen segmented and furnished with a segmented tail-appendage (postabdomen).

Eoscorpius anglicus Woodward (England), *E. carbonarius* Meek and Worthen (Illinois), *Microlabis Sternbergi* Corda (Bohemia), *Cyclophthalmus senior* Corda (Bohemia), *Mazonia Woodiana* Meek and Worthen (Illinois).

While justified in the main in this arrangement, Karsch's definitions of the groups are both insufficient, and to some extent based on altogether subordinate characteristics. The discovery of new American

forms enables me to supplement, and, as I believe, to improve these, and accordingly the following systematic sketch of paleozoic Arachnida has been prepared, into which have been thrown such suggestions and new facts as have come to hand.

ORDER ANTHRACOMARTI Karsch.

Body more or less depressed, the cephalothorax and abdomen distinctly separable. Cephalothorax frequently made up in large part of pedigerous segments more or less wedge-shaped, and visible above as well as below, the arrangement of which corresponds to that of the coxæ. The abdomen forms a single mass, and is composed of a variable number of visible segments, ranging from four to nine. Palpi not much longer than the legs, simply terminated.

Fam. ARTHROLYCOSIDÆ Harger.

Cephalothorax orbicular, twice as large as the abdomen. Coxæ radiating from a central pit. Abdomen oval, much narrower at base than the cephalothorax, with no longitudinal sculpturing, and composed of seven segments. No abdominal appendages.

ARTHROLYCOSA Harger.

Arthrolycosa antiqua Harger, Amer. Journ. Sc. Arts, (3,) vii. 219–223 (fig.), 1874. Mazon Creek, Illinois.

In his description of this arachnid, Harger inclines to the belief that the terminal segment of the palpus is chelate. He says (*loc. cit.*): "The third [joint] is broken near its proximal articulation, and the connection of this appendage with what seems to be its distal cheliform segment is unfortunately imperfect. This segment is also poorly preserved, and the articulation of its digit is only to be seen with a good magnifier and in a certain light. . . . I do not, however, consider the forcipulate character of this segment beyond a doubt. It is perhaps not improbable that it may have been modified much as in the males of ordinary spiders, and not truly forcipulate."

Having reason, by its undoubted relationship to other forms of Anthracomarti, to doubt the forcipulate character of the palpus, of which Harger speaks so doubtfully, Professor Marsh kindly permitted me to study the type in Yale College Museum, and I find on close examination that not only is the joint in question not chelate, but it terminates by a straight, transverse suture, and is followed by a portion of another, apparently short, terminal joint.

Fam. POLIOCHERIDÆ nov. fam.

Cephalothorax quadrate, not much smaller than the abdomen. Coxæ radiating (apparently) from a median line. Abdomen rounded, of equal breadth with the cephalothorax, with very indistinct or no longitudinal sculpturing, and composed of only four segments, of which the basal is very short. No abdominal appendages.

POLIOCHERA nov. gen.

Cephalothorax scarcely longer than broad, slightly narrowing anteriorly, the front square. Legs stout, moderately long. Abdomen full, at base as broad as the cephalothorax, broadening slightly behind, fully rounded, the first segment about one third the length of the others, which are equal.

Poliochera punctulata nov. sp. Body minutely, deeply and uniformly punctate throughout, excepting on the narrow first abdominal segment, which is smooth. Legs similarly punctate. Length 15 mm., greatest breadth 7.5 mm. Mazon Creek, Illinois (R. D. Lacoe, No. 1845). A fuller description and figure will be given at another time.

Fam. ARCHITARBOIDÆ Karsch.

Cephalothorax of variable form, but at least half as large as the abdomen. Coxæ radiating from a middle point or line, or from a triangular sternal piece, its base on the abdominal margin. Abdomen orbicular or oval, at base as broad or nearly as broad as the cephalothorax, with a lateral ridge on each side converging toward the anus, the surface moderately smooth; segments seven to nine in number, the basal ones visible below, though often extremely shortened in the middle; no abdominal appendages.

GERAPHRYNUS nov. gen.

Cephalothorax fusiform, angulated in front, nearly as large as the abdomen. Coxæ radiating from a median line. Palpi slenderer than the legs, longer than the cephalothorax, springing from its extreme front and of uniform size throughout. Abdomen subfusiform, composed of nine segments, rounded behind, with no constriction at the base; a large triangular post-thoracic plate, crowding the middle of the first five short segments out of a straight transverse line. Readily distinguished from Architarbus by its produced and angulate cephalothorax.

Geraphrynus carbonarius nov. sp. Cephalothorax faintly punctu-

late, its posterior portion and the post-thoracic plate more distinctly, while the abdomen is profusely and rather sparingly punctate. Length 20 mm. Greatest breadth 10 mm. Mazon Creek, Ill. (Coll. R. D. Lacoe, No. 1701.) A fuller description and figure will be given at another time.

The specimen is interesting as preserving very completely the left palpus.

Architarbus Scudder.

Cephalothorax orbicular, broadly rounded in front, much smaller than the abdomen, but not separated from it by a marked lateral constriction. Coxæ radiating from a central pit. Abdomen oval, composed of nine segments, of which those on the basal half are very much shorter than the others, and on the dorsal surface are forced still more closely together by the large post-thoracic plate.

Architarbus rotundatus Scudder, Worth. Geol. Ill., iii. 568, fig. 4, 1868. Mazon Creek, Ill.

Architarbus subovalis Woodward, Geol. Mag., ix. 385–387, pl. 9, fig. 1^a, 1^b, 1872. Lancashire, England. Here probably belongs *Curculioides Ansticii* Buckl. Geol., ii. 76, pl. 46″, fig. 1, 1837. Coalbrookdale, England.

Architarbus silesiacus Roemer, Jahresb. schles. Gesellsch. vaterl. Cult., lvi. 54, 55, 1879. Glatz, Silesia.

Anthracomartus Karsch.

Cephalothorax quadrate, the front square or scarcely convex, about half the size of the abdomen ; coxæ radiating from a broad triangular sternal plate, the base of which forms the posterior margin. Sides of the body constricted so as to show a distinct though generally slight separation of cephalothorax and abdomen. Abdomen orbicular, composed of seven segments of similar length throughout.

Anthracomartus Völkelianus Karsch, Zeitschr. deutsch. geol. Gesellsch., 1882, pp. 556–561, pl. 21, figs. 1, 2. Neurode, Silesia.

Anthracomartus Krejčii Kušta, Sitzungsb. böhm. Gesellsch. Wiss., October 12, 1883, pl., figs. 1–3, 1883. Rakonitz, Bohemia.

Anthracomartus trilobitus nov. sp. Sides of the cephalothorax angulated in the middle of the posterior half, behind which it narrows rapidly, showing a very marked constriction between it and the abdomen. The latter of equal length and width, broadest behind the middle, and furnished with a marginal flange nearly as broad as the lateral fields. Whole body delicately and uniformly punctate. Length 17.5 mm.; greatest width 11.25 mm. Fayetteville, Ark.

This interesting species was found in some abundance by Rev. F. S. Harvey in the subconglomerate coal measures about six miles north-east of Fayetteville. It differs from all the other species in the remarkable posterior narrowing of the cephalothorax. A fuller description and figure will be given at another time.

Anthracomartus pustulatus nov. sp. Cephalothorax narrowing somewhat forward. Abdomen longer than broad, oval, broadest in the middle, the longitudinal ridges converging regularly and considerably in straight lines, the whole surface of body closely covered with very irregularly polygonal sunken cells, giving the whole body a pustulate appearance. Length 15 mm.; greatest breadth 7.5 mm. Mazon Creek, Ill.

This species was received from Mr. R. D. Lacoe (No. 1752), and differs conspicuously in its rough surface structure from all other species. A fuller description is deferred.

Fam. EOPHRYNOIDÆ Karsch.

Cephalothorax quadrate, narrowing strongly in front, or triangular, less than one third the size of the full abdomen, broken dorsally into many plates. Coxæ radiating from a median furrow. Abdomen ovate orbicular, much broader than the cephalothorax, from which it is separated laterally by a distinct constriction; segments nine or ten in number, some of the basal segments obscured below, the dorsal plates either broken by irregular longitudinal sutures into one median and two lateral fields, or furnished with many longitudinal series of stout tubercles, or both; the penultimate and antepenultimate segments bearing lateral terminal spines.

KREISCHERIA Geinitz.

Cephalothorax subquadrate, with three large median plates, one in front and two behind, and on each side three smaller lateral plates. Dorsum of abdomen broken by oblique sutures, crossing each segment laterally subparallel to the lateral margin, into a median and lateral fields, of which the median is about as large as the combined lateral fields.

Kreischeria Wiedei Geinitz, Zeitschr. deutsch. geol. Gesellsch., 1882, pp. 238–242, pl. 14, figs 1, 2. Zwickau, Saxony.

This species was referred correctly by Geinitz to the vicinity of Eophrynus, but by Karsch considered as belonging to the Opiliones in the neighborhood of Trogulus. The structure of the cephalothorax, though very different in general appearance from that of Eophrynus,

is essentially identical with it, and the abdomen only differs in essential points from that of Eophrynus in characters which ally it to the Architarboidæ.

Eophrynus Woodward.

Cephalothorax triangular; its dorsal surface tumid, completely broken into great tuberculate bosses, arranged in a lateral row down either side and a median row dividing in two at the posterior margin. Dorsal surface of abdomen with two lateral rows of large rounded tubercles and a median row of large stellate tubercles, besides being sometimes divided by longitudinal sutures into median and lateral fields.

Eophrynus Prestvicii Woodward, Geol. Mag., viii. 385–387, pl. 11, figs. 1, 2, 1871. *Curculioides Prestvicii* Buckland, Geol., ii. 76, 77, pl. 46″, fig. 2, 1837. Coalbrookdale and Dudley, England.

The discovery of new remains of this curious arachnid led Mr. Woodward to notice the incorrect reference of similar remains by Buckland and Samouelle to the Coleoptera. As stated above, it seems probable that the other species referred in the same place to the Coleoptera will prove to be an Architarbus. Woodward neither figures nor makes mention of any fracture of the dorsal plates in his very excellently preserved specimen; but as this exists in the next species, it would seem probable that they might have been overlooked.

Eophrynus Salmi Stur, Abhandl. geol. Reichsanst., viii. ii, p. v, note (fig.), 1877. Ostrau, Moravia.

The generic name is incorrectly spelled Euphrynus.

Order PEDIPALPI Latreille.

Geralinura nov. gen.

Cephalothorax ovate, the front rounded, one third as broad as hinder portion. Palpi large and robust, with interior spines. First two pairs of legs slender, the hinder stout and broad. Abdomen composed of nine joints, the basal three rather short, the others subequal and longer. Postabdomen much as in Thelyphonus.

Geralinura carbonaria nov. sp. Hinder legs three times as stout as the front pairs, the fourth much longer than the third. Abdomen about twice as long as broad. Postabdomen composed first of two joints together half as long as broad, one third as broad as the abdomen, next of a single quadrate joint, followed by the thread, about one fourth or one fifth as broad, of unknown length, with numerous

joints about twice as long as broad. Length to end of abdomen proper, 13.5 mm. Mazon Creek, Ill. (R. D. Lacoe, No. 1754.) Fuller description deferred.

The discovery of this fossil is one of the most interesting in this field in recent years, as it is the first of the Pedipalpi yet found in paleozoic rocks, or perhaps in any deposits, and it differs from modern types no more than do the carboniferous scorpions. It was brought to my notice after the rest of this paper was in type.

ORDER SCORPIONES Thorell.

In his paper in the Transactions of the Royal Society of Edinburgh, where he added so much to our knowledge of fossil scorpions, Mr. B. P. Peach remarks that, "although there seems to be sufficient reason to separate the genus [Eoscorpius] from any recent one, these ancient scorpions appear not to differ in any essential character from those now living"; and Dr. A. Geikie, in commenting on Mr. Peach's discoveries in "Nature" (vol. xxv. pp. 1–3), says, "It is obvious that the scorpion has remained with hardly any change since carboniferous times." Geikie also notices that "the chief difference between the living scorpion and its ancient progenitors lies in the fact that in the fossil forms the mesial eyes are much larger in proportion to the lateral ones, and also to the size of the whole animal."

There are, however, some points in the structure of these paleozoic forms which show that they differ from modern types more than the above statements would appear to warrant. In the only one of Mr. Peach's figured specimens showing clearly the under surface of the cephalothorax, we find that the coxæ of the second pair of legs do not touch along the middle line of the body, as in all living forms, (where they cut off anteriorly the so-called sternum,) but are separated by a pair of independent plates — the sternites apparently of the second thoracic segments — which lie in advance of the sternum proper.

In addition to this, the structure of the comb, upon which in part the families of living scorpions are based, differ remarkably from all recent forms, if we are to judge solely by the information Mr. Peach has given us. In all living types the combs are made up (1st) of a variable number of longitudinally disposed lamellæ. These form an anterior row, composed of two or three (generally three) plates, the basal much the larger; a posterior row of numerous minute rounded scales, and an intermediate series more or less numerous, disposed in from one to three longitudinal rows, of which the basal ones are the larger, and the others generally larger than those of the posterior row, excepting

when there is more than one intermediate series. (2d.) Besides these, there is a single marginal row of processes, the teeth of the comb, which are as numerous as the scales of the posterior row to which they correspond.

To judge from Mr. Peach's figures and descriptions, the anterior row, which in modern scorpions forms the backbone of the comb, and is mostly made up of a single plate very broad at base, is just as weak in structure as the intermediate lamellæ, which are also excessively reduced and multiplied; or perhaps the anterior row is entirely wanting, and its place occupied by a vegetative development of the "intermediate" series, a view which might be re-enforced from what is known of Meek and Worthen's species. The teeth also in one of Mr. Peach's examples are represented apically by a "double row of leaflets, which overlap in an imbricating manner like tiles." On the other hand, the figure which Fritsch has given us of Corda's Bohemian species resembles modern types much more closely except in the entire absence of the intermediate series, throwing some doubt upon the constancy of the characters apparently derivable from the other sources.

The differences which exist should certainly not be ignored, and it may lead to an earlier decision of the question whether distinctions any broader than mere generic ones may separate the earlier from the modern forms, if we place these paleozoic forms in a distinct family, and endeavor to define their characteristics. This we propose doing under the following provisional characters.

EOSCORPIONIDÆ nov. fam.

A pair of sternal plates interposed visibly between the coxæ of the second pair of legs. Posterior sternal plates, corresponding to the "sternum" of living scorpions, quadrate, large, of about equal length and breadth. Both intermediate and dorsal lamellæ of the combs very numerous, rounded and small, subequal, and not larger than the fulcra, arranged in many rows, the teeth numerous and forming a single row toward the base of the comb, but a double imbricated row apically. Hands slender. Mesial eyes very large and elevated. Five lateral eyes of equal size on each side, forming a single continuous semicircle around and behind the mesial eyes.

EOSCORPIUS Meek and Worthen.

Eoscorpius carbonarius Meek and Worthen, Geol. Ill., iii. 560–562, fig., 1868. *Buthus? carbonarius* Ibid., Amer. Journ. Sc. Arts, (2,) xlvi. 22–24, 1868. Mazon Creek, Ill.

Eoscorpius anglicus Woodward, Quart. Journ. Geol. Soc. Lond., 1876, p. 58, pl. 8, figs. 2–3, 3^a, 5. Mansfield, England.

Eoscorpius euglyptus Peach, Trans. Royal Soc. Edinb., xxx. 402–404, pl. 22, figs. 3–3^d, 1882. River Esk, Scotland.

Eoscorpius glaber Peach, Trans. Roy. Soc. Edinb., xxx. 400–402, pl. 22, figs. 2–2^1, 1882. Scotland.

Eoscorpius inflatus Peach, Trans. Roy. Soc. Edinb., xxx. 405, 406, pl. 23, figs. 12–12^d, 1882. River Esk, Scotland.

Eoscorpius tuberculatus Peach, Trans. Roy. Soc. Edinb., xxx. 398–400, pl. 23, figs. 8–8^h, 1882. Scotland.

Cyclophthalmus Corda.

Cyclophthalmus senior Corda, Verhandl. Gesellsch. vaterl. Mus. Böhm., 1835, pp. 38–43, pl., figs. 1–14; Fritsch, Fauna Steink. Böhm., 9–14, pl. 1, figs. 1–8, pl. 2, figs. 1–6, 2^c, pl. 3, fig. 4, 1874. *Microlabis Sternbergi* Corda, Verhandl. Gesellsch. vaterl. Mus. Böhm., 1839, pp. 15–18, pl. 1, figs. 1–5. Bohemia.

Fritsch has shown Corda's two species to be but one.

Mazonia Meek and Worthen.

Mazonia Woodiana Meek and Worthen, Geol. Surv. Ill., iii. 563–565, figs. A–D, 1868. Mazon Creek, Ill.

Other paleozoic scorpions have been found in Permian strata at Nyřan, Bohemia (Fritsch, Fauna Gaskohle Böhm., i. 32, 1879), and in carboniferous stumps at the Joggins, Nova Scotia (Scudder, Phil. Trans. 1882, p. 650). Additional specimens in my hands from Mazon Creek have not been studied.

Order ARANEÆ.

Suborder TERRITELARIÆ Thorell.

Fam. LIPHISTIOIDÆ Thorell.

Protolycosa Roemer.

Protolycosa anthracophila Roemer, Neues Jahrb. Miner., 1866, pp. 136–141, pl. 3, figs. 1–3. Thorell, Eur. Spiders, 221, 222, 1870. Kattonitz, Upper Silesia.

Palaranea Fritsch.

Palaranea borassifolia Fritsch, Fauna Steink. Böhm. 8, pl. 2, fig. 7, 1874. Bohemia.

IV.

CONTRIBUTIONS FROM THE NEWPORT MARINE LABORATORY, COMMUNICATED BY ALEXANDER AGASSIZ.

XIV. ON THE DEVELOPMENT OF SOME PELAGIC FISH EGGS. — PRELIMINARY NOTICE.

By Alexander Agassiz and C. O. Whitman.

Read May 14th, 1884.

Considerable attention has in late years been paid to fish eggs found floating on the surface, more especially since the establishment of various Fish Commissions to study the history of the sea-fishes. As early as 1868, Malm[1] raised the eggs of a species of Flounder by artificial fecundation, and found them to float on the surface at first, and in the later stages of development to sink gradually below the surface. Sars,[2] in 1869, found that the eggs of the Cod floated on the surface. Haeckel,[3] during a visit to Corsica, in 1874, also found pelagic fish eggs which he referred to some Gadoid: he subsequently found the same eggs at Nice, in 1876. E. van Beneden,[4] in 1874, studied pelagic fish eggs at Villa Franca. Kupffer,[5] in 1868, published some interesting investigations on pelagic fish eggs found in the harbor of Kiel.

Mr. Ryder[6] and Colonel McDonald of the United States Fish Commission observed that the eggs of the Spanish Mackerel were found floating on the surface.

In 1879 and in 1882 A. Agassiz[7] published some preliminary results on the pelagic fish eggs he had raised during the past twenty

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1 Malm, A. W. Svenska Vetensk. Akad. Handl., VII., 1867 and 1868.

2 Sars, G. O. Indberetninger til Departementel for det Indre. Christiania, 1869.

3 Haeckel, E. Die Gastrula und die Eifurchung. Jena Zeitschr., IX., 1875.

4 Van Beneden, E. Quart. Journ. Mic. Sci., 1878, p. 41.

5 Kupffer, C. Archiv für Mikr. Anat., 1868, p. 209.

6 Ryder, J. A. Bull. U. S. Fish Com., I., p. 136, 1881.

7 Agassiz, A. Proc. Am. Acad, vol. xiv., 1878, p. 1, and vol. xvii., 1882, p. 27.

years, some of them belonging to the Flounder, to Ctenolabrus, to Cottus, to Lophius, and to Tautoga.

According to Emery,[8] the eggs of Fierasfer are also pelagic. Kingsley and Conn[9] have also studied the pelagic eggs of Ctenolabrus; they state that Mr. Van Vleck has observed those of Merlucius, and also figured an egg with an oil globule; and finally Hensen[10] has published a most interesting paper on the occurrence of the eggs of a few of the fishes of the Baltic at the surface.

During the season of 1883 a good deal of the difficulty, and consequent confusion, existing in distinguishing the many species of pelagic eggs met with during the summer at Newport, has been evercome, and we are now able to distinguish no less than twenty-two species of pelagic eggs, nearly all of which have been referred to some of the many young stages of osseous fishes which have been collected at the surface for a series of years.

The differences between these pelagic eggs are very slight, and the greatest possible care is necessary not to confuse eggs of very dissimilar fishes. I may give as an instance that the eggs of *Ps. melanogaster* and of an undetermined Flounder had, till this year, been confounded with those of Ctenolabrus; those of the Brown Flounder with those of two species of osseous fishes as yet undetermined; those of a species of undetermined Flounder with those of Hemitripterus; and those of the Sienna Flounder with those of the Yellow Flounder. As these different pelagic eggs must go through extensive changes in the course of their development, changes in the appearance and growth of pigment spots of the body and of the yolk, it is almost impracticable, without any extensive series of sketches, to establish with certainty the identity or difference of closely allied eggs. Hensen has called attention to the ellipsoidal shape of some of the pelagic fish eggs; this is particularly striking in the egg of an Osmerus (?); in this the difference between the longer and the shorter axis can be detected by the eye. The yolk mass of this egg is remarkable for being segmented in large polygonal cells; a similar, but incomplete segmentation occurs in the eggs of the Brown Flounder.

The pigment spots of the surface of the yolk, and those characteristic of different species of fish embryos, begin to make their appear-

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[8] Emery, C. Fierasfer. Arbeit aus d. Zool. Station, zu Neapel.

[9] Kingsley, J. S., and H. W. Conn. Mem. Boston Soc. Nat. Hist., III., No. VI., 1883.

[10] Hensen, V. Bericht der Com. zur Wiss. Untersuchung der deutschen Meere, IV. Kiel, 1883.

ance at very different times in the many species we have examined. Hence, until the characteristic pigment pattern of an embryo is pretty well known, it is easy to confound the eggs of very different species. The position and shape of the otoliths and the degree of development of the pectorals become also excellent guides to the identification of eggs well advanced in their development. The differences in the young embryos on hatching are very considerable, and in these earlier stages the degree of development of the head, the proportional size of the yolk-bag, the shape of the embryonic fin, the position of the vent, and the pattern of the pigment spots, are all of great use in the identification of the species.

It is remarkable that no monstrosities have ever been picked up among the large number of pelagic eggs examined during the past twenty years, while among the eggs raised by artificial fecundation, the number of eggs which do not develop is very considerable. It is true, that unfertilized eggs, after a day or two, probably fall to the bottom, and are rapidly decomposed, or eaten by other animals. As the majority of the species of Flounders, of which the pelagic eggs have been found, live together in considerable numbers, it is probable that at the time of fecundation but few eggs escape being fertilized: the same is the case with Ctenolabrus, Tautoga, and other shallow-water species. The pelagic eggs are, of course, at the mercy of the winds and waves, and are found in the greatest abundance in the streaks formed by tidal eddies and by winds, which are everywhere on the sea-coast such excellent collecting ground for embryos of invertebrates and for other pelagic animals.

We have collected at Newport the pelagic eggs of six species of Flounders, two species of Cottus, those of Ctenolabrus, Tautoga, Osmerus, and Lophius, and have in collection the eggs of ten species of fishes as yet not determined; but they are probably the eggs of Motella, of Labrax, of Poronotus, and of the Bluefish. The exact identification of these eggs must be deferred to another season. Several of the eggs have been referred to the species of Flounder and other young fishes which were figured in former papers of Mr. Agassiz in the Proceedings of the American Academy of Arts and Sciences.

The presence or absence of an oil globule is an excellent guide in the identification of the egg; the size of this globule is, however, quite variable. In one of the species of Cottus there are many globules present, and the number of these varies from sixteen to thirty-two for this species. In another species, Hemitripterus, in which there is generally only one globule, it is not an uncommon occurrence to find two globules.

Closely allied species of Flounders are found to have eggs either with or without an oil globule. The question naturally arises how far in one and the same egg the number of globules may vary. I have followed an egg in which in some stages the number of globules varied in number from day to day. These pelagic eggs all appear to have a great number of minute fatty globules scattered through the yolk mass; these may or may not unite in a single or in many globules, or may always remain scattered in the yolk. It is undoubtedly to the presence of these minute fatty globules and the larger oil globules that the pelagic eggs owe their capacity for floating. Many pelagic eggs undoubtedly sink in the latest stages of growth.

The number of these pelagic eggs is very great. Hardly a day passes when the fishing with the surface-net does not bring in a number of eggs. The spawning season of many of the fishes which lay pelagic eggs is not very long: at any rate, the different eggs succeed one another quite rapidly, and of the twenty-one species of pelagic eggs thus far observed at Newport, none extend over a greater period than six weeks. The statement I had made, that the eggs of Ctenolabrus were found during the whole summer, rests on the incorrectness of the identification of pelagic eggs closely resembling those of Ctenolabrus, and which are collected in the last part of July and during August.

As the data for the exact determination of some of these eggs are still incomplete, we defer publishing them until they can be supplemented with the observations of another season.

During the summer of 1883, our attention was directed mainly to the earlier stages of development, embraced between the fecundation of the egg and the complete formation of the embryo. The numerous researches on the embryology of the teleostean fishes leave many points of fundamental importance yet to be settled. In evidence of this, we need only refer to the parablast theories that have appeared since the investigations of His; the contradictory views concerning the origin of the so-called "free nuclei" which appear beneath the blastoderm, and the part they play in building up the embryo; the controversies relating to the manner in which the embryo is formed; and the widely different views respecting the origin of both the mesoderm and the entoderm. Kupffer's vesicle still remains a complete mystery; and no one has thus far succeeded in giving a complete and satisfactory account of the origin of the germ-ring ("embryonic rim," Balfour).

No attempt has been made to explain *how* the alimentary canal is formed; and the precise origin of the chorda and its mode of differ-

entiation are questions which have not been exhausted. Some of the general features of the cleavage have been understood since the time of Rusconi;[11] and the researches of Ryder and Hoffmann have demonstrated the existence of polar globules, pronuclei, and karyokinetic figures, in addition to numerous other facts of both special and general importance. But it is manifest that our knowledge in this direction, invaluable as it is, is very far from having reached that degree of completeness with which we are familiar in the case of some other vertebrates, and many invertebrates. The importance of accurate and detailed study of the cleavage phenomena has been illustrated in so many cases in recent years, that it is now fast becoming unnecessary to insist upon it.

Remembering that the histogenetic sundering of the embryonic material actually begins with the cleavage, and that "jeder einzelne Entwicklungsmoment ist die nothwendige Folge des vorausgegangenen und die Bedingung des folgenden,"[12] it seems clear what course our investigations should take in order to reach satisfactory conclusions on the origin and relation of the germ-layers. But in all telolecithal vertebrate ova, especially those extreme forms in which the cleavage is restricted to a discoidal mass aggregated at one pole, the difficulties in the way of tracing the precise genealogy of individual cells soon become quite insurmountable. Notwithstanding the exceptional advantages for observation afforded by transparent pelagic fish eggs, no one has hitherto succeeded in tracing the exact genetic relationship of each cell beyond the 16-cell stage.

In passing from the 16-cell to the 32-cell stage, the central portion of the blastodisc becomes two cells deep, and on this account it becomes extremely difficult, beyond the latter stage, to trace the genesis of the individual cells in the living egg. By the aid of mounted preparations we have found it possible to obtain the complete genealogical history of each cell as far as the 64-cell stage. In leaving this stage the blastodisc becomes three cells deep in its central portion, and we have been unable to carry the complete identification of all the cells beyond this point. Fortunately, the more interesting among the concluding phenomena of the cleavage are confined to the marginal cells of the disc; and it is the history of these cells that we have been able to follow with sufficient completeness to decide one of the cardinal questions in the early development of the teleostean fishes,

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11 Müller's Arch., 1836, p. 278.

12 Leuckart and Bergmann. Vergl. Anat. u. Phys. d. Thierreiches, p. 19.

namely, the precise origin of what His and others have called the "parablast." The results of our investigation on this point enable us to say that this layer, the origin and nature of which have been the subject of so much controversy since the time of Lereboullet, corresponds to what is found in all vertebrate ova with discoidal cleavage, and lend strong support to the opinion that its mode of origin is in all cases essentially the same. As these results appear to be irreconcilable with those recently published by Hoffmann,[13] it is proper that we should here state the methods by which they have been reached.

Methods.

1. The successive phases of the cleavage, beginning with the moment of fecundation, were first of all followed many times over in the living egg. Profile views and optical sections were obtained by tilting the microscope, the tube being inclined at different angles between the vertical and horizontal positions, as recommended by Kingsley and Conn. The eggs were confined in a live-box, and the light controlled by the aid of Zeiss's illuminating apparatus (after Abbe). Two complete series of vertical optical sections were obtained by the camera lucida, one parallel with the longer, the other with the shorter axis of the blastodisc.

2. Mounted preparations of the blastodisc, in every stage of development from the time when the pronuclei appear up to the time when the germ-ring begins to form, were made in large numbers. I have experimented with all the hardening reagents in common use, and have failed to find any completely satisfactory method of preserving the vitellus. Even the germinal disc cannot be well preserved by any of the ordinary hardening fluids. Kleinenberg's picro-sulphuric acid, for instance, causes the cleavage products to swell, and in many cases to become completely disorganized. The embryonic stages can be hardened in chromic acid (one per cent), but the yolk contracts considerably without becoming well hardened. The best preparations of the cleavage stages have been obtained with osmic acid followed by a modified form of Merkel's[14] fluid. This fluid, as used by Dr. Eisig, consists of chromic acid (one fourth per cent) and platinum chloride (one fourth per cent) mixed in equal parts. Thus prepared it causes maceration of the embryonic portion of the egg. By using a stronger chromic acid (one per cent) and combining it as

[13] Hoffmann, C. K. Zur Ontogenie der Knochenfische, Amsterdam, 1881.
[14] Merkel. Ueber die *Macula lutea* des Menschen, Leipzig, 1870, p. 19.

before with the same volume of platinum chloride (one fourth per cent), everything may be well preserved and hardened except the yolk. But this fluid cannot be used with success unless the egg has been first killed by another agent; for eggs placed in this fluid continue to live for a considerable time, and may even pass through one or two stages of cleavage. It is therefore necessary to use some reagent that kills instantly. For this purpose a weak solution of osmic acid may be used.

The eggs are placed in a watch-glass with a few drops of sea-water, and then a quantity of osmic acid (one half per cent) equal to that of the sea-water is added. After five to ten minutes the eggs are transferred to the mixture of chromic acid and platinum chloride, and left for twenty-four hours or more. This fluid not only arrests the process of blackening, but actually bleaches the egg to a considerable extent. After this treatment it is an easy matter to separate the blastoderm from the yolk by needles; and the preparations thus obtained may be stained at once, and then treated with alcohol and mounted in balsam.

The value of such preparations must be measured by the accuracy and clearness with which they present the conditions in the living state. A careful study of the preparations shows that the method can be relied on in every particular. The osmic acid fixes the living conditions more perfectly than any other reagent at present known, and the chrom-platinum mixture completes the work of hardening without shrinkage or swelling. The finest details of the cleavage lines, the cleavage cavity, and the nuclear figures, are well preserved. The relation of the blastoderm to the protoplasmic mantle enveloping the vitellus, and all the particulars in regard to the origin of the so-called "free nuclei," are satisfactorily shown. No violence is required in order to free the blastoderm from the yolk, as a clean separation is usually effected by the action of the acids. In this separation the protoplasmic mantle invariably goes with the blastoderm, in the older as well as in the younger stages of development.

3. For sectioning, the embryonic portions of the egg need not be separated from the yolk. But before transferring the eggs from the chrom-platinum solution to the different grades of alcohol (fifty to one hundred per cent), the egg-membrane should be broken or perforated by the aid of needles on the side opposite the blastoderm, in order that the alcohol may reach the egg readily, as otherwise the membrane wrinkles badly, and often injures the embryonic portion. For the embryonic stages, the above method of hardening has not been

altogether satisfactory. The embryos are brittle, and the boundary lines between the different parts are not always sufficiently clear. A few of these stages were hardened in Perenyi's fluid,[15] and the sections have proved much more instructive than any obtained from eggs hardened in other fluids. Perenyi's fluid consists of four parts of nitric acid (ten per cent); three parts of alcohol (ninety per cent); and three parts of chromic acid (one half per cent).

Perenyi recommends leaving eggs from four to five hours in this fluid, then transferring to seventy per cent alcohol (twenty-four hours), strong alcohol (several days), and finally absolute alcohol (four to five days). Two hours' immersion is certainly sufficient for pelagic fish eggs, and probably even a shorter time would do. Among the methods of staining recommended by Perenyi may be mentioned that of mixing borax-carmine or picro-carmine with the hardening fluid. The addition of the staining fluid produces a precipitate, which should be removed by filtering. The filtered mixture both hardens and stains at the same time, which is certainly an advantage. After an immersion of a few hours in this fluid, the eggs should be transferred first to fifty per cent alcohol (five hours), then to successively higher grades. This method of hardening does not render the eggs brittle.

General Remarks on the Ovum.

Although historical summaries and general discussions must be deferred until our observations are published in full, it may be well to define at once our view in regard to what constitutes the teleostean ovum, since recent authorities differ very much on this point; and to call attention to a few general considerations which bear more or less directly on the much disputed question of the origin of the subgerminal nuclei. Bibliographical references will be limited to such as serve to make clear the points under consideration.

In harmony with the view generally received since the publication of Gegenbaur's[16] researches on meroblastic vertebrate ova, we regard the teleostean ovum as a simple cell, agreeing in all the more fundamental features of its constitution, not only with the avian, the reptilian, and the selachian ovum, but also with the holoblastic ovum of the mammal, of the amphibian, of the cyclostome, of the ganoid, and of Amphioxus.

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[15] Perenyi. "Eine neue Erhärtungsflüssigkeit." Zool. Anz., No. 119, p. 459, 1882.

[16] Gegenbaur. Müller's Arch., 1861.

We agree, substantially, with Klein[17] in the following statement: "The fact that the parablast has, at the outset, been forming one unit with what represents the archiblast (blastoderm, auct.), and, *while increasing, has spread, i. e. grown over, the yolk* which underlies the segmentation cavity, is, I think, the most absolute proof that the yolk is as much different from the parablast as it is from the archiblast." But we do not find in this a valid argument for the opinion that the yolk of the teleostean ovum has no homologue in holoblastic vertebrate ova.[18 & 19] On the contrary, we maintain, with Balfour,[20] Waldeyer,[21] and others, that the genesis of the ovum and the absence of any sharp delimitation between the protoplasm and the deutoplasm before impregnation, show conclusively that the latter is an integrant portion of the ovum. The discovery by Balfour (No. 20, pp. 57, 90) and Schultz[22] of a protoplasmic network ("Keimfortsätze," Waldeyer) extending throughout the yolk in the elasmobranch ovum, and the discovery by Van Bambeke[23] of "fines traînées protoplasmiques qui partent en rayonnant de la base du disque et plongent dans la sphère vitelline," in the unfecundated ovum of osseous fish, make it sufficiently evident that the food-yolk cannot be regarded as adventitious material in either case. When we reflect that among telolecithal vertebrate ova a complete series of graduations in the segregation of formative from nutritive material are found between the amphibian ovum and the teleostean ovum, we find it impossible to accept any theory of the constitution of the ovum which is not broad enough to include *both* extremes. The positive evidence in favor of the view here maintained does not lie, as supposed by Balfour, in the conversion of the periblast ("parablast," auct.) into a cellular layer, but *in the actual cleavage of the yolk in some teleostean ova, as first noted by Mr. Agassiz.*

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17 Klein, E. "Development of Common Trout." Quart. Jour. Mic. Sci., XVI., p. 127, 1876.

18 Ryder, John A. "Development of Silver Gar." Bull. U. S. Fish Com., I., p. 295, 1881.

19 "Observations on the Absorption of the Yolk, the Food, Feeding, and Development of Embryo Fishes." Bull. U. S. Fish Com., II., p. 199, 1882.

20 Balfour. Development of Elasmobranch Fishes, pp. 57, 89–90, 1878.

21 Waldeyer. "Archiblast und Parablast." Arch. f. Mik. Anat., XXII., Heft 1, 1883.

22 Schultz, Alex. "Zur Entwicklungsgeschichte des Selachiereies." Arch. f. Mik. Anat., XI., 1875.

23 Van Bambeke. "Recherches sur l'Embryologie des Poissons Osseux." Mém. Cour. et Mém. de Sav. Étrang. de l'Acad. Roy. Belgique, XL., 1875.

The teleostean ovum affords a beautiful illustration of what Lankester[24] has designated as "precocious segregation"; for here the separation of germinal material from food-yolk becomes complete, or nearly so, before the cleavage process begins; and even the blastodisc and the periblast, at first continuous, soon part company without the direct intervention of cleavage. In these respects this ovum represents a higher type than does the elasmobranch ovum; but there is another respect in which the reverse seems to be true. The fact that the entire germ-ring enters directly into the embryo certainly points to a more primitive mode of embryonic formation than is seen in the elasmobranch ovum. In this particular the elasmobranch ovum represents an intermediate condition between the teleostean and the avian ovum. How is this fact to be reconciled with the opinion that the teleostean ovum represents a later type than that of the elasmobranch? We are of the opinion that it can be best explained on the hypothesis first suggested by Balfour,([20]) that the teleosts are derived from a type of fish with a much larger ovum. The presence of an enormous mass of food-yolk in the elasmobranch ovum retards the closure of the blastopore, and the general effect is the same as if the formation of the embryo had been greatly accelerated. The result is that the embryo is already formed and constricted off from the yolk before the blastopore closes. In precisely the same way we may explain the still more extreme case of the chick. Assuming that there has been a large reduction of food-yolk in the ovum of the osseous fish, we may safely conclude that the closure of the blastopore has been correspondingly hastened; and it is the comparatively early closure which renders possible the inclusion of the entire germ-ring in the embryo. Thus the apparently earlier type of development exhibited in osseous fishes may be explained as a case of reversion.

A very marked polar differentiation characterizes the mature teleostean ovum. Hatschek[25] was the first to call attention to the universality and the early appearance of polarity in the egg; and Balfour[26] has pointed out the influence of the polar concentration of the vitellus in determining the various forms of cleavage. Von Baer[27] defines very clearly the axis of the frog's ovum, and its relation to the

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24 Lankester. Notes on Embryology and Classification, for the Use of Students. London, 1877.

25 Hatschek. "Pedicellina." Zeitschr. f. Wiss. Zool., XXIX., p. 502, 1877.

26 Balfour. Comparison, etc. Quart. Journ. Micr. Sci., p. 210, 1875.

27 K. E. von Baer. "Die Metamorphose des Eies der Batrachier." Müller's Arch., p. 484, 1834.

first cleavage planes, which he designates as *meridian*, *equatorial*, and *parallel;* but the general significance of these relations has hitherto passed unnoticed. Mark[28] comes very near to this point, when he states that the axis of the ovum is probably homologous throughout the metazoa, and adds that the "maturation spindle" always lies in this axis. We would carry the generalization one step farther, and say it is highly probable that *the first cleavage-spindle invariably lies at right angles to the axis of the ovum throughout the metazoa; and that therefore the first cleavage-plane is always a meridian plane,* at least in all cases where the first cleavage-spindle is accompanied by cleavage. As the evidence now stands, we cannot affirm that this rule is universal; but it is so general that the few cases which might be urged as exceptions, can hardly weaken its importance. Among the gastropods we find a very peculiar departure from this rule, in the case of *Nassa mutabilis*[29] and *Modiolaria* (Crenella) *marmorata* Forb.[30] It is easy to see, however, that the cleavage in these gastropods forms no real exception. The equatorial division of the ovum of Nassa, described by Bobretzky as beginning just before the meridian cleavage appears, is nothing more nor less than a *constriction* which simulates a cleavage-plane. That it is not a proper cleavage is shown by its entire behavior, and by the position of the first cleavage-spindle. But what explanation can be given of this constriction, which after appearing twice vanishes without accomplishing anything? We shall undertake later to show that this phenomenon is only one of many kindred phenomena which may all be ascribed to nuclear influence; and shall content ourselves here by comparing it with the constriction that comes and goes around the blastodisc of the teleostean ovum, during the early stages of cleavage. It is the same influence which causes the germinal protoplasm to concentrate in the form of a polar disc, and to thicken up until it forms a sort of calotte. The protoplasm gathers up around the two poles of the first cleavage-spindle, as if they were two centres of attraction; and simultaneously the outward manifestations of the tendency of each half of the disc to assume a spherical condition appear in the form of a meridian

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[28] E. L. Mark. "Maturation, Fecundation, and Segmentation of Limax campestris." Bull. Mus. Comp. Zoöl., VI., Part II. No. 12, p. 512, 1881.

[29] N. Bobretzky. "Studien ü. d. emb. Entw. d. Gastropoden." Arch. f. Mik. Anat., XIII. pp. 98–105, 1877.

[30] Lovén. "Bidrag till Kännedomen om Utvecklingen af Mollusca Acephala Lamellibranchiata." Kongl. Vetensk. Akad. Handl., 1848. (Translation, Arch. f. Naturgeschichte, XV. Jahrg., 1849, p. 312.)

cleavage-groove, and a more or less distinct constriction between the margin of the disc and the yolk.

In Nassa the two blastomeres succeed in attaining a completely spherical form and the equatorial constriction is carried to the point of separation. As soon, however, as the meridian cleavage is finished, one of the blastomeres coalesces with the deutoplasmic mass, and the result is two very unequal cleavage-spheres. The second cleavage-plane, which is also a meridian plane, at right angles to the first, is accompanied by the same equatorial constriction, and followed by a coalescence which completely cancels the effect of the constriction, leaving a stage of four blastomeres. Leaving these constrictions out of account, as forming no part of the proper cleavage, we may say that the ovum of Nassa follows the general law of cleavage, in beginning with two meridian grooves.

According to Brooks,[81] the early stages of cleavage in the oyster are identical with those in Nassa. The "exceptions to the normal method of segmentation" plainly demonstrate that the trefoil and the cinquefoil stages represent, in reality, the 2-cell and the 4-cell stages.

The fact, if it be a fact, that the axis of the ovum is homologous in the higher animals, implies much more than has yet been stated. It implies that certain definite and fundamental relations are predetermined in the unsegmented ovum, among which may be mentioned constant relations, first, between the poles and the germ-layers; second, between the axis of the ovum and the axis of the embryo; and third, between both these axes and the first cleavage-planes. For reasons which do not require to be stated here, there is a much higher probability that the first one or two cleavage-planes sustain uniform relations with the axis of the ovum, than that the later planes do so. We cannot here enter into a discussion of the general bearing of these several points; but one of these, viz. the relation of the first cleavage-plane to the axis of the ovum, deserves something more than a passing notice in this connection. It is somewhat surprising, in view of the facts now before us, that recent writers have gone on talking about cleavage as if it were nothing extraordinary for it to begin with an equatorial or parallel groove. It is plainly a matter of fundamental importance, especially in ova with a pronounced polar segregation of material, whether the first cleavage-plane passes through the pole from which the polar globules issue, or at right angles to the axis

[81] Brooks. "Development of the Oyster." Studies from the Biolog. Lab., I., No. 4, 1880.

of the ovum. In one case there would be a simple division of material; in the other, a histogenetic sundering of substances, which ordinarily comes as one of the concluding events of cleavage. The natural order is unquestionably two meridian cleavages followed by an equatorial or horizontal cleavage; and we have yet to see decisive evidence that this order has been completely inverted in any single instance. Polar segregation has been carried to such an extreme in some ova that it practically amounts to a complete separation of food-yolk from the formative material; and, if we mistake not, the line of separation thus established has, in a few instances, been mistaken for an equatorial cleavage. Something of this kind has happened in the case of Nassa and Crenella, and we venture to suggest that it *may* have occurred in that of Balanus and Scalpellum.[33]

In a single octavo plate Haeckel[34] has described the development of a gastropod (*Trochus?*) and a chætopod (*Fabricia*) as far as the gastrula stage. He speaks of an axis which has its poles in the "animal" and "vegetative" halves of the ovum, and which becomes characterized either before or during the process of cleavage. The cleavage of the gastropod ovum conforms to the rule before stated; while that of the chætopod, to all appearances, proceeds on a fundamentally different plan. In Fabricia the first cleavage-plane *appears* to be an equatorial plane, separating the ectodermic from the entodermic pole. As Haeckel's figures are designed to illustrate the formation of the gastrula rather than to give the details of cleavage, it would be unjust to criticise them too closely in the latter respect. Before, however, Fabricia is put down as a real exception to the general rule, one or two points must be cleared up by further investigation. It is by no means certain that the first cleavage-plane is not meridian, instead of equatorial as it appears to be. The relation of the polar globules to the plane of division would decide the question.

Haeckel's views are, however, irreconcilable with those here maintained; for he states that the first cleavage-plane *generally* divides the ovum into two unlike parts, "a smaller animal cell, the mother-cell of the exoderm, and a larger vegetative cell, the mother-cell of the entoderm"; and cites Fabricia, the rotifera, and the gephyrea as examples.

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32 Rabl. "Entwick. d. Tellerschnecke." Morphol. Jahrb., V., pp. 573–584, 1879.

33 Lang. "Die Dotterfurchung von Balanus." Jena Zeitschr. f. Naturw., XII., p. 671, 1878.

34 Haeckel. No. 3, p. 425, Pl. XXIV.

In the rotifera, according to Salensky's[35] observations on *Brachionus urceolaris*, the first cleavage-plane is equatorial; and this is followed by two meridian cleavages of the smaller sphere. Had Salensky succeeded in finding polar globules and in tracing *circumstantially* the origin of the 5-cell stage, we could have no hesitation in conceding the full force of the exception. The eggs of the rotifera are by no means favorable objects for deciding the question under consideration. No satisfactory evidence of polar globules in these ova has been obtained. If these ova develop parthenogenetically, as supposed by Cohn[36] and Huxley[37]; and if, on this account, no polar globules are produced, it might be possible to explain the appearance of an equatorial cleavage prior to the meridian planes of cleavage. The archiamphiaster which gives rise to the polar globules always lies in the axis of the ovum, and its plane of division is therefore parallel to the equator of the ovum. If the division of the archiamphiaster led to the division of the ovum, instead of the formation of a polar globule, the first cleavage-plane would be equatorial or parallel.

In regard to the gephyrea, Haeckel is certainly in error, in proof of which we may refer to the investigations of Selenka[38] on Phascolosoma, and of Spengel[39] on Bonellia. A comparison of Selenka's figs. 1 and 2, Pl. XXIX., with Haeckel's figs. 93 and 94, Pl. XXIV., will show how easily a meridian cleavage, where the polar globules have not been observed, could be mistaken for an equatorial one.

The researches of Van Beneden[40] on the maturation, fecundation, and cleavage of the mammalian ovum, of which we have thus far received only a preliminary account, leave it doubtful whether the first cleavage-spindle is parallel with the axis of the ovum or at right angles to it. He calls attention to the pronounced polarity of the ovum, but expressly states that he has not yet obtained a complete history of the first cleavage-spindle.[41] The relation of the plane of first cleavage to the axis of the ovum is therefore undetermined. If

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[35] Salensky. Zeitschr. f. wiss. Zool., XXII., p. 456, 1872.

[36] Cohn. Zeitschr. f. wiss. Zool., VII., 1856.

[37] Huxley. Trans. Micr. Soc., 1853.

[38] Selenka. Zeitschr. f. wiss. Zool., XXV., p. 444, 1875.

[39] Spengel. Mitt. a. d. Station z. Neapel, I., p. 374, 1879.

[40] E. van Beneden. "La Maturation de l'Œuf, la Fécondation et les premières Phases du Développement Embryonnaire d. Mammifères." Bull. de l'Acad. Roy. des Sci. de Belgique, December, 1875. Also in Journal de Zoologie, V., 1876.

[41] Id. "Formation des Feuillets chez le Lapin." Arch. de Biol., I., pp. 140, 141, 1880.

the first cleavage divides the ectodermic from the entodermic pole, as supposed by Van Beneden, it is most probably equatorial. If further researches prove that the cleavage begins with an equatorial groove, a very important exception to the general rule will be established. If, on the other hand, it turns out that the first cleavage is meridian, it will be difficult to reconcile this fact with Van Beneden's opinion on the destination of the first two cleavage-spheres.

The nematode ovum presents some difficulties, the importance of which we would not underestimate. Goette[42] has followed the cleavage with such accuracy and detail that he feels warranted in asserting that the first cleavage divides the ovum into two parts *which show no regular differences of size, form, or color*, but which must nevertheless be regarded as unlike in character, since one gives origin to the ectoderm and the other to the entoderm. Goette gives no information in regard to nuclear transformations, and nothing definite on the polar globules further than that they are first seen at one (aboral) end of the ovum, and that they change position so as to be of no use in orientation. The long axis is regarded as the axis of the ovum, and the first cleavage as equatorial, since it cuts the axis at right angles near the middle. Unlike most observers, Goette does not overlook the fact that this is an exception to the general mode of cleavage among the vermes; and he explains it as the result of the confinement of the ovum in a stiff ellipsoidal membrane, which prevents the ovum from elongating transversely, as it would naturally do if the cleavage plane coincided with the long axis (l. c., p. 65). Goette's observations form a most valuable contribution on the promorphology of the vermian ovum. He recognizes a homologous axis, an ectodermic and an entodermic pole, and uniform relations between the axis of the ovum and that of the embryo, and between the poles and the dorsal and ventral surfaces. All these relations become evident in the development of the nematode, the moment we take account of the fact that the cleavage process, in adapting itself to the form of the egg-membrane, causes the ovum to rotate on its transverse axis through 90°.

The very interesting discovery made by Auerbach,[43] that the pronuclei perform a rotation of 90° on an axis perpendicular to the longitudinal axis of the ovum, just before the cleavage begins, confirms the opinion that there is a transposition of cleavage-planes, at least in the case of *Rhabditis nigrovenosa* and some other nematodes.

[42] Goette. Abhandl. z. Entw'gesch. d. Tiere, Erstes Heft, p. 59. Leipzig, 1882.

[43] Auerbach. Organologische Studien, II., p. 212, 1874.

In *Tylenchus*, *Anguillula*, and *Rhabditis dolichura*, according to Bütschli,[44] the case is different; for here the first cleavage, although at right angles to the longer axis of the ellipsoid, is meridian, if the exit of the polar globule determines the position of the axis of the ovum.

From the foregoing examples it will be seen that the exceptions in the direction of the first cleavage-plane are neither so numerous nor so serious as might at first be supposed. For the most part they are cases in which the data for exact orientation have escaped detection, either because the difficulties in the way of direct and connected observation were not surmounted, or because the attention of the observer was not brought to bear on the point we are here considering.

But why, it may be asked, should there be any uniformity in the direction of the first cleavage-plane? What are the antecedent conditions or relations which determine this uniformity? It is a well-known fact that the nuclear spindles of one cell-generation tend to arrange themselves at right angles to those of the preceding generation. The primary spindle (archiamphiaster), at the moment when it divides to form one of the polar globules, almost invariably coincides with the axis of the ovum;[*] and hence the first cleavage-spindle usually assumes a position perpendicular to this axis, and the corresponding cleavage falls in a meridian plane. The primary or "maturation spindles" assume a radial position, evidently in obedience to what is known as the polarity of the ovum; and the arrangement of successive spindles is regulated by the polarity of the blastomeres to which they belong, and by the interaction of these polarities. The uniformity in the direction of the first cleavage plane is then only an outward manifestation of a more fundamental uniformity in the constitution of ova, and herein lies its significance.

From this point of view, it is not the rule so much as the exception which stands in need of explanation. In a spherical ovum developing under normal conditions, there are no mechanical causes interfering with the ordinary course of events, in a manner to bring about the substitution of an equatorial for a meridian cleavage. The polar concentration of the germinal material would plainly have the contrary effect; and, when carried to the extreme seen in the teleostean ovum, would present conditions that are not only favorable to the normal position of the first cleavage-spindle, but actually unfavorable to any other position.

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44 Bütschli. Studien ü. d. ersten Entwicklungsvorgänge der Eizelle, etc., pp. 19–22, 1876.

* Cucullanus forms an interesting exception, according to Bütschli, No. 44.

While insisting on the constancy and uniformity of promorphological relations as the foundation of all later homologies, we are not unmindful of the recent important investigations of Pflüger[45] on the influence of gravitation on the division of cells.

These investigations have been carried through with all the skill of a master hand, and they have brought to light a multitude of very astonishing facts, many of which bear directly on the points above presented. Of the accuracy of the results there is no room for a shred of doubt; but the validity of the general conclusions is, in some very important particulars, much more than doubtful. For the present, we shall limit our remarks to one or two points on which our views differ most materially from those of Pflüger. The following conclusion, for example, is based on the assumption of a complete "isotropy" of the ovum, — an assumption most emphatically contradicted by the observations.

"*Das befruchtete Ei besitzt gar keine wesentliche Beziehung zu der spätern Organisation des Thieres, so wenig als eine Schneeflocke in einer wesentlichen Beziehung zur Grösse und Gestalt der Lawine steht, die unter Umständen aus ihr sich entwickelt. Dass aus dem Keime immer dasselbe entsteht, kommt daher, dass er immer unter dieselben äussern Bedingungen gebracht ist.*"

Place this *conclusion* by the side of the following *observation:* —

"Die Embryonalanlage wird aber *stets* gefunden auf derjenigen Hälfte des lotrechten primären Meridianes, welche bei schief liegender primärer Achse die *obere* ist. Abermals entscheidet die Beziehung zur Richtung der Schwerkraft. *Die einzelnen Theile einer Meridianhälfte können nun nicht als gleichwertig betrachtet werden.* Niemals sah ich die erste Entstehung der Rusconi'schen Oeffnung und des centralen Nervensystems auf der schwarzen Hemisphäre. *Sie entstehen stets vom weissen Gürtel des tertiären Aequators aus. Hier ist der Krystallisationspunkt der specialisirten Organisation. Von hier aus entsteht der Kopftheil des Nervensystems stets in der Richtung nach dem schwarzen, der Steisstheil in der nach dem weissen Pol.*"

One of the more important among these remarkable discoveries, the general significance of which seems to have been overlooked, is the transit of Rusconi's opening across the white hemisphere of the ovum. This opening, beginning as a horizontal cleft at one point in the equator, was found to shift its position gradually *backwards* until

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[45] E. Pflüger. Archiv f. d. ges. Physiol., XXXI., pp. 311–318, and XXXII., pp. 1–79, 1883. Abstr. in Biolog. Centralblatt, III., No. 19, pp. 596–601.

it reached a point on the opposite side of the equator. This extremely interesting fact reveals a fundamental agreement between the frog and the fish in regard to the mode of formation of the embryo.

By fixing the frog's ovum in abnormal positions, at the time of fecundation or soon after, Pflüger has shown conclusively that the *direction* of the first two cleavage-planes will invariably be vertical, whatever be the position of the ovum; and from this he concludes that the line of intersection of these cleavage-planes coincides, under normal conditions, with the axis of the ovum, *for no other reason than that this axis happens to represent the direction of gravitation.* In other words, gravitation determines the vertical direction of the first cleavage-plane entirely independently of any pre-established axial relations. Now such a conclusion stands in plain contradiction with our general knowledge of cleavage; and indeed is refuted, in our estimation, by Pflüger's own observations. Why is it that the first cleavage-plane is invariably meridian in the ovum of the fish, not only in those cases where the blastodisc lies at the upper or lower pole, but also in those exceptional cases noticed by Ryder and others where it lies at one side of the vitellus? If the cleavage-plane must follow the direction of gravitation in the first instance, then why not in the third? What means this invariable *order* in the succession of the early cleavage-planes? Pflüger should be the last man, after his experiments, to declare that the order is the same because the outward conditions are the same. If it is the purpose of the cleavage merely to split up the germinal material into small pieces, and a matter of utter indifference in what order this is accomplished, how does it happen that in the teleostean ovum, according to our observations, *the first cleavage-plane coincides with the median plane of the embryo?* And is it merely a remarkable coincidence that, according to the concurrent testimony of both Pflüger and Roux,[46] precisely the same relation holds in the ovum of the frog? Or shall we infer that because this relation between the first cleavage-plane and the median plane of the embryo may be reached by two modes of cleavage, "es ist ziemlich gleichgiltig in welcher Reihenfolge die vorschreitende Zerkleinerung sich vollzieht"?

If gravitation were the sole controlling and guiding agency in cleavage, its effect ought to be *instantaneous*, and it should be possible to change the direction of a cleavage-plane already in progress. The

[46] Wilhelm Roux. Ueber d. Zeit d. Bestimmung d. Hauptrichtungen d. Froschembryo. Leipzig, 1883.

impossibility of doing this is demonstrated by Pflüger's experiments, and herein we find an insuperable objection to his theory. Again, if one cleavage-plane has no definite and constant relation to antecedent and subsequent planes, its direction being under the exclusive control of gravitation, it should be possible to turn the second cleavage-plane out of its normal relations with the first cleavage-plane, by turning the ovum *after* the first cleavage-groove appears. Experiments directed to this end also gave negative results. The same holds true of the third cleavage, and probably of all subsequent ones.

A very suggestive fact was brought out in regard to the third cleavage. If the ovum was turned upside down immediately *after* the appearance of the second cleavage, the position of the third cleavage was not affected; but if the inversion of the ovum preceded by an hour or more the beginning of the first cleavage, then the third cleavage appeared in a parallel plane in the unpigmented half of the ovum, and this pole went on segmenting more rapidly than the black pole. The *time* required to bring about such a remarkable transposition of the third cleavage-plane suggests *a corresponding internal transposition of the active protoplasmic matrix of the ovum.* If a body constituted like the ovum is restrained by artificial means from taking its normal position, a redistribution (Umlagerung) of material must immediately set in and continue until the equilibrium is restored. The active basic portion of the ovum, having a lower specific gravity than the passive nutritive elements, would eventually recover its normal position, and thus the virtual axis of the ovum would inevitably right itself in spite of the inability of the ovum to rotate bodily. From this point of view, we may still hold that there is a constant relation between the axis and the cleavage-planes, and that the first two of these are vertical because the axis is vertical, and not because this is the direction of gravitation.

Cleavage.

Our observations on the cleavage have been most complete in the case of Ctenolabrus; for here we have followed its entire course from the moment of fecundation onward; and our observations on the living ovum have been supplemented by a study of sections, and of several complete series of mounted preparations. We have followed the cleavage phenomena with somewhat less detail in *Pseudorhombus melanogaster*, *Ps. oblongus*, and Tautoga, but with sufficient care to warrant us in saying that they are in no essential respect different from those observed in the ovum of Ctenolabrus.

From the time when the pronuclei appear to the moment when the first cleavage-groove begins, is a short period of not more than thirty minutes; but it is a period of special interest in the history of the nuclei, as will presently be seen. We have watched this period through twice on artificially fertilized ova, and not less than a dozen times on ova taken directly from the sea. The Newport Laboratory is so near the place from which most of our material was derived, that we found no difficulty in obtaining ova from five to ten minutes after fecundation.

The polar disc, to which cleavage is at first restricted, has received a variety of names. It is the "Anschwellung" of Rusconi; the "Bildungsdotter" of Reichert; the "ampoule du germe," or "vitellus formateur" of Lereboullet; the "archiblast" of His; the "blastodisc" of Haeckel; the "disque germinatif," "germinal disc," "Keim," of various writers; and is the exact equivalent of the "discus proligerus" (Von Baer) of the chick. It gives rise to the "cap," "calotte blastodermique," or "blastoderm," of later stages. We shall employ for this portion of the ovum the term *blastodisc*, since it is a word now in general use, and is not burdened with any of the theories connected with the use of the name "archiblast."

The thinner portion of the protoplasmic mantle of the ovum is also known under various names. It is called "membrane vitellaire" by Vogt; "Dotterhaut," by Oellacher; "membrane interne," "feuillet muqueux," by Lereboullet; "couche intermédiaire," by Von Bambeke; "intermediate layer," by Von Beneden; "parablast," by His; "pellicle," "yolk-hypoblast," by Ryder. As the name "parablast" has been used in very different senses by His, Klein, Hoffmann, Waldeyer, and others, it seems best to employ a new term, which is at least free from confusing associations. For this portion of the ovum we propose the name *periblast*, — a name which has the advantage of not prejudging the question of the origin and destination of the part it designates.

Blastodisc and *periblast* are simply names for two portions of one and the same envelope, which invests the vitelline sphere. In all the ova we have studied the blastodisc occupies the lower pole; but for purposes of comparison it will be convenient to speak of this as the upper, or *ectodermic pole;* and of the opposite, as the lower, or *entodermic pole.* The vertical line joining these two poles is the *axis of the ovum.*

The peculiarities in the development of the ovum will be best understood by regarding it as an amphibian ovum, in which the active pro-

toplasm has taken a peripheral position; and in so doing has avoided the necessity of splitting up a large mass of passive food material. *The central portion of the blastodisc represents the active portion of the pigmented hemisphere of the frog's ovum; while the marginal portion of the disc, together with the periblast, represents the active portion of the unpigmented hemisphere.* This correspondence is made evident by the course of events described in the sequel. The prevailing opinion, that the blastodisc alone undergoes cleavage, and that the periblastic cells have a different mode of origin, is entirely erroneous. The only difference between the holoblastic and the meroblastic types of cleavage, beyond what has just been mentioned, results from a difference in the rapidity with which the cleavage advances from the ectodermic towards the entodermic pole. In the frog's ovum the *first* cleavage-planes eventually reach the entodermic pole; in the teleostean ovum, the embryo begins to form before the cleavage reaches the equator of the ovum. But if the correspondence above stated be borne in mind, it will be seen that the equator of the frog's ovum does not correspond with the equator of the teleostean ovum, but with the marginal zone of the blastodisc. The ectodermic and entodermic hemispheres are not very unequal in the ovum of the frog; but in the teleostean ovum there is an enormous disparity between their morphological equivalents. The polar concentration of the active constituents of the ovum in the latter case has reduced the ectodermic hemisphere to a polar disc, and enlarged the entodermic hemisphere until it embraces nearly the whole sphere. As most of the material of the entodermic hemisphere lies in the margin of the blastodisc and the adjoining portion of the periblast, it is plain that it takes a direct share in the process of cleavage. Remembering then that *the virtual equator of the teleostean ovum lies in the marginal zone of the blastodisc*, we shall find it possible to arrive at clear and comprehensive views respecting the entire course of cleavage, the peculiarities in the origin and growth of the germ-layers, and the manner in which the embryo is formed.

In the mature ovum, the whole protoplasmic envelope of the vitellus is charged with minute shining granules, which render it partially opaque. A few minutes after fecundation nearly all the granules have dissolved, leaving the entire ovum completely transparent. The same remarkable change was observed in the ovum of the Blackfish.

At the time of clearing up, a shadowy ring, enclosing a clear central area, becomes visible at the ectodermic pole. Tilting the microscope to a horizontal position, a profile view is obtained which shows

that the shadowy ring is due to the polar aggregation of the protoplasm. The clear central space is the place in which the pronuclei will soon become visible. Our observations on the formation of the polar globules are not yet completed; and for the present may be passed over with the single remark, that these bodies do not escape through the micropyle in the case of Ctenolabrus.

At the time the pronuclei appear, the blastodisc has a low conical form, the rounded summit of which is directed towards the centre of the vitellus. The peripheral, basal portion scarcely swells beyond the niveau of the egg-sphere, and its margin thins out gradually into the periblast. There is a thin, but distinct perivitelline space separating the zona radiata from the blastodisc and the upper half of the periblast. The axis of the blastodisc is vertical, coinciding with that of the ovum. One or two polar globules are seen in the perivitelline space, at the octodermic pole. The fluid filling this space is not pure water, as shown by the fact that it becomes finely granular in acids, and stains in carmine solutions.

Pronuclei. — The earliest view of the pronuclei that we have obtained represents them as two equal spheres (.01 mm. in diameter) already in contact. The male pronucleus lies directly above the female, so that a line joining their centres would pass through the point of contact and coincide with the axis of the ovum. These bodies have a smooth and distinct outline, and a slightly granular composition. In general appearance they do not differ from the nuclei of the blastomeres.

In a mounted preparation of the blastodisc, which was killed thirty minutes after the ova and spermatozoa were mixed, the male pronucleus lies at some distance above the female pronucleus. The latter is spherical (.007 mm.) and surrounded by radial lines; while the former has an elongated ovate form (.009 × .004 mm.), the larger end of which is nearest the female pronucleus. This form of the male pronucleus recalls that of the "male aster," as described by Fol[47] in the ovum of *Sagitta Gegenbauri.*

We have several times watched the conjugation of the pronuclei continuously, from the moment of contact to that of complete coalescence. The two spheres flatten against each other, the line of junction remaining distinct until each has assumed the form of a hemisphere. This stage is reached in seven minutes after first contact. The line of junction now becomes obscure, first in the middle, then at

[47] Fol. Recherches sur la Fécondation, etc., 1879, Pl. X. figs. 6 and 7.

the ends; and at the end of eleven minutes, reckoning from the moment of contact, the coalescence is complete, and we have a perfect sphere .02 mm. in diameter. Within one minute this sphere undergoes a transformation, which ends in the formation of the first cleavage-amphiaster. *This amphiaster has a horizontal position, at right angles to the axis of the ovum.* From the moment when this transformation begins to the moment when the first cleavage-groove appears, is only eight minutes. Thus the conjugation of the pronuclei and the formation of the first cleavage-amphiaster require twenty minutes. We have found very little variation from these figures.

From the above measurements it is evident that the pronuclei increase somewhat in volume during the few minutes (10–12) consumed in the conjugation. A similar fact was observed by Bütschli in the ovum of *Nephelis* (No. 44, p. 6), and more recently by Mark in the ovum of *Limax* (No. 28, p. 220).

In the mounted preparation just referred to, I can discover no distinct astral lines around the body which we regard as the male pronucleus.*

It is an interesting fact, that *the first cleavage-spindle is parallel with the plane of junction of the pronuclei*, precisely as in the ova of many invertebrata. If this spindle were vertical, as supposed by Hoffmann, we should expect to see a rotation of the pronuclei, like that described by Auerbach in the ovum of Rhabditis. No such event occurs in the ova we are describing.

The Velocity of Cleavage. — From the appearance of the first cleavage-groove to the moment of hatching is but little more than fifty hours in any of the species we have followed. This period was only forty hours in *Ps. oblongus.*

We have traced the genesis of the amphiastral figures to the ninth generation in Ctenolabrus. The time that elapses between the first cleavage-amphiaster and the ninth generation of amphiasters was ascertained in one case to be two hours and sixteen minutes. The time between successive generations of amphiasters diminishes as the cleavage advances. Between the first and second generation twenty minutes passed; between the second and third, also twenty minutes; between the third and fourth, eighteen minutes; and from this point onward the time diminishes gradually, until, between the eighth and ninth generations, only fifteen minutes intervene.

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* Mark (l. c., p. 221) finds that the male pronucleus (Limax) is accompanied by an astral figure only in abnormal cases.

Van Beneden was the first to call attention to the fact, "that the time which elapses between two successive phases of cleavage is shorter and shorter as the cells diminish in volume, and in consequence of such diminution."* As only about twenty minutes elapse between the moment of first contact of the pronuclei and the appearance of the first meridian cleavage-groove, it is plain that we have no time for an equatorial cleavage to take place between these two events. Thus, at the very outset, we meet with facts that appear to be utterly irreconcilable with Hoffmann's account of the origin of the periblastic nuclei. It remains for us to show precisely how these nuclei arise; and to ascertain whether there are really two very different modes of cell-genesis introduced by the division of the first, or of any subsequent, cleavage-amphiaster.

The Growth of the Blastodisc at the Expense of the Periblast. — The moment the coalesced pronuclei enter the amphiastral phase of activity, an important change in the form of the blastodisc sets in, which gradually transforms it into a calotte-shaped mass in the course of the first four cleavage-stages. These form-changes are especially noteworthy, inasmuch as they confirm and emphasize the fact already stated, that *the first cleavage-amphiaster cuts the vertical axis of the blastodisc at right angles.* If this amphiaster had a vertical position, as asserted by Hoffmann, and the accompanying cleavage-plane a horizontal position, then the axis of the blastodisc would *lengthen* during the process of division. Now just the reverse of this takes place. The axis shortens so rapidly that within five minutes after the amphiaster appears (*Ps. melanogaster*) it is reduced to little more than half its original length. In order to watch the progress of these changes the microscope must have a horizontal position, so that a profile view may be obtained. The inner conical face of the blastodisc flattens very rapidly, and concomitantly the peripheral face becomes slowly more convex. At the end of five minutes (we are now speaking of *Ps. melanogaster*) the blastodisc has the form of a double-convex lens, with outer and inner surfaces of very nearly equal curvature. Two minutes later it has a meniscoidal form, the convex outer face almost or quite in contact with the egg-membrane, and the concave inner surface moulded to that of the vitelline sphere. It holds this form for about five minutes, during which it becomes somewhat thicker *at the expense of the periblast.* Ten minutes after the disappearance of

* Van Beneden first noticed this fact in the ovum of *Gammarus locusta,* and of the rabbit, No. 4, p. 46.

the first cleavage-nucleus, the first cleavage begins, not by a groove on the external surface of the blastodisc, but by one on the internal face. *The early cleavages are all introduced by grooves running from the inner towards the outer surface of the blastodisc.* These introductory grooves, which have hitherto been entirely overlooked, but which are very conspicuous in all the teleostean ova we have studied, reach their greatest height (which is seldom more than one third the thickness of the blastodisc) at the moment when the grooves from the external surface begin. We may call these *inferior*, in distinction from the external, or *superior* grooves. The peculiarity of these grooves is that they *precede* the appearance of the superior grooves, and that they recede and rapidly disappear after the superior grooves begin. The first of these inferior grooves begins as a shallow rounded furrow, but usually culminates in a sharp angle. At the moment of culmination we have several times been able to recognize a differentiated vertical plane extending completely through the blastodisc, from the edge of the inferior to the edge of the beginning superior groove. The plane of division is then already established before an actual separation begins. This foreshadowed plane of division is visible in mounted preparations quite as early as any traces of division in the chromatic elements of the nucleus.

In five or six minutes after the inferior groove appears, the corresponding superior groove begins; and as it deepens, the inferior groove closes up and becomes completely obliterated in the course of eight or ten minutes. By this time the superior groove has cut fully half-way through the blastodisc, and its walls begin to close together, so that the deeper portion of the groove, seen in profile, has the form of a vertical line, while its upper portion opens widely in a funnel-like form. It is at this time that the second generation of nuclei become visible. Gradually the linear portion of the groove lengthens, *upward* by the closure of the funnel-shape space, and *downward* by descending towards the inner surface. But the plane of division has not yet reached the floor of the blastodisc; nor does it do this until some minutes after two new amphiasters have formed, and the second inferior groove is already well advanced (twenty-one minutes after the first inferior groove). The floor is reached first of all at the point where the second inferior groove crosses the path of the first superior groove. Nearer the margin of the blastodisc, where this is continuous with the periblast, the floor is not reached until considerably later. During all this we have looked in vain for any distinct trace or shadowy indication of a lower stratum, which, according to Hoff-

mann, becomes split off by a horizontal plane of division before the first meridian cleavage appears. Equally fruitless has been our search for this Hoffmannian stratum in mounted preparations and sections. Not only is there no such splitting, but the whole course of events thus far is incompatible with such an operation.

A series of optical sections obtained by the aid of the camera, at intervals of one to four minutes during the first cleavage, is exceedingly instructive. At the time the meniscoidal form is reached, there is still no boundary line between the periblast and the blastodisc. The blastodiscal portion of the protoplasmic envelope thins out gradually, and passes with even outlines into the periblastic portion, which, after passing the equator, becomes very thin. At every step it is very evident that the blastodisc is thickening and broadening at the expense of the periblast. At the time the first cleavage begins, the blastodisc has an oval form, with only a broad, shadowy outline, as seen from the inner surface. As the cleavage-groove descends, the margin of the disc thickens and the adjoining periblast becomes thinner. At the time the two new nuclei appear, the outlines of the blastodisc begin to clear up; but they do not attain their sharpest definition until a few moments after the second amphiastral stage is reached. Seen from the surface, the blastodisc now appears to be separated from the periblast by a clear-cut boundary line; but a profile view shows that the continuity is still unbroken. The illusive appearance is due to the abruptness with which the thickened margin of the blastodisc rises above the periblast.

Soon after the second amphiastral phase appears, we notice that the blastodisc begins to expand in the direction of its shorter horizontal axis; i. e. in a direction at right angles to the coming (second) cleavage-plane. At the same time the margin of the blastodisc begins to lose its sharp outline in surface views, especially at those points in or near which the second cleavage-groove is to terminate. Optical as well as actual sections show that the blastodisc is thinning out at these points, so that the boundary line between it and the periblast is again only a little less obscure than at first. With the appearance of the third generation of nuclei, the outlines begin to clear up again, becoming sharper and sharper, until a maximum limit is reached soon after the introduction of the third amphiastral phase.

Thus towards the close of each of these earlier amphiastral divisions there is an obscuration of boundary lines, especially at the marginal extremities of the incipient cleavage-grooves, followed in each case by a gradual clearing up, which culminates in the early part of

the succeeding amphiastral phase. At every clearing up we observe that the blastodisc is increasing in size, while the periblast becomes thinner and thinner. There can be no doubt about the fact that the blastodisc actually draws the larger portion of the periblast into itself during the first four cleavage-stages.

We have seen that each cleavage-stage comprises two distinct acts: first, an *expansion* which accompanies the elongation and division of the amphiasters; and second, a *contraction* or *concentration* of the protoplasm around the new generation of nuclei. At each succeeding contraction, or *systole* as it might be called, a portion of the periblast becomes incorporated into the blastodisc; and the outcome of this is, that the latter thickens up and soon presents the form of a calotte. The question naturally arises, What determines these relations between the blastodisc and the periblast? It is evident that there is some attractive force in the blastodisc which is absent from the periblast; and further, that *this force, whatever it may be, increases during the cleavage.* Now the nucleo-plasm is the only substance, so far as we can ascertain, which is contained in the blastodisc and not contained in the periblast; and it is a very interesting fact that *this nucleo-plasm increases at a much more rapid rate than the blastodisc.* We cannot here enter into a discussion of the nature of the nuclei; but the conclusion is unavoidable that the attractive power of the blastodisc resides either (1.) in the nuclei; or (2.) in a *special* portion of the protoplasm intimately associated with the nuclei in the process of division; or (3.) in both. So far as the question we are here considering is concerned, it is a matter of indifference which hypothesis we adopt.

The cleavage process not only increases the number and volume of the nuclei, but it distributes them throughout the blastodisc. It is the establishment of these centres of attraction in the margin of the blastodisc, which accounts for the transformation of the blastodisc into a cap-like body. *Pari passu* with the multiplication of these centres, the blastodisc rises above the niveau of the egg-sphere. Its margin thickens up at the expense of the periblast, becomes steep at the end of the first cleavage, thicker and slightly rounded at the end of the second, more strongly rounded (forming a re-entrant angle with the periblast) at the conclusion of the third, and deeply constricted from the egg-sphere during the 16-cell stage. The progressive deepening of the re-entrant angle carries the zone of junction a short distance under the margin of the blastodisc, giving thus the appearance of a complete separation from the periblast. But the continuity is still preserved, and is destined to remain for some time to come.

The 16-cell stage marks an epoch in the history of teleostean development. The median plane of the embryo is given with the first cleavage-plane, so that a longitudinal and a transverse axis are determined from the outset; but a more precise orientation is not attainable before the 16-cell stage. At this time we are generally able (in Ctenolabrus) to recognize *antero-posterior* relations, and with these a *right* and a *left* side. From this stage onward we recognize also a *difference of constitution* between the *central* and the *marginal* cells.* This distinction is brought out clearly in most of our mounted preparations obtained by the use of osmic acid followed by the chrom-platinum solution. As the contrast becomes more pronounced as cleavage advances, and as it eventually ends in a decided histological differentiation, its appearance at this stage must be regarded as an early anticipation of events realized at a much later date.

The relations now established between the blastodisc and the periblast, although fundamentally the same, are not so simple and unmistakable as at first. A precise knowledge of these relations is not readily attainable by a study of the living ovum. Actual sections and mounted preparations are required for this purpose. Vertical sections of this stage show that only the twelve marginal cells rest on the yolk.

The shaded portion of Fig. 1 shows how much of the floor of these cells is in contact with the yolk. The four central cells and an adjoining zone of the marginal cells form the roof of a shallow cleavage-cavity, of which we shall have more to say farther on. The floor of this cavity is formed by a very thin stratum of the periblast. This sub-germinal stratum becomes apparent in some cases as early as the 8-cell stage. In some of our sections it is in contact with the central cells, but seldom shows traces of fusion with them. In Fig. 2 all these relations are accurately shown. The periblast (p) joins the marginal cells at their inferior outer angle, and from this point to the point (cl) which marks the limit of the cleavage-cavity there is not the slightest trace of a periblastic layer. This region may be designated as the *zone of junction* (z). No nuclei are to be found in any portion of the periblast at this time. As to the origin of the sub-germinal periblast seen in this stage, we can state positively that it does not arise by a horizontal cleavage. It is a portion of the periblastic material which works its way under the blastodisc con-

* Rauber noticed this fact in the ovum of Gobius, but gave no explanation of it. Morph. Jahrb., VIII., p. 287.

comitantly with the formation and expansion of the cleavage-cavity. From this stage onward the history of the periblast is the history of the cleavage of the marginal cells. Our success in tracing this history is largely due to the methods employed. It was the differential staining before mentioned that first placed us on the right track.

One or two points insisted on by Hoffmann deserve notice in this connection. Hoffmann's ideas respecting the manner in which the cleavage of the teleostean ovum is introduced were fully anticipated by E. van Beneden, in 1878.* "Directly after fecundation," says Beneden, "the egg of the Osseous Fish divides into two very unequal cells, very dissimilar, differing in constitution and significance; the one is the germ which segments and from which the blastodisc is derived; the other is formed by the deutoplasmic globe, clothed, at least partially, by a thin layer of protoplasm forming 'the intermediate layer.'" (No. 4, p. 54.) Hoffmann brings, in addition to his observations, the following *a priori* consideration to the support of this view: —

"Wenn das Ei der Knochenfische eine Zelle ist, worüber man wohl nicht mehr streiten wird, dann ist es auch ganz natürlich, dass bei der eintretenden Furchung, bei der ersten Theilung in Archiblast und Parablast, der erste Furchungskern die Theilung einleitet, sonst würde hier der Fall vorliegen, dass eine Zelle sich theilte, ohne dass der Kern sich daran betheiligte und in dem einen Stück unverändert liegen blieb, während das andere Stück kernlos wurde." (No. 13, p. 126.)

These two citations are sufficient for the present to show precisely how this matter stood at the beginning of our investigations. The evidence produced by Hoffmann in favor of his and Van Beneden's view is of a very positive character, and can only be impeached by calling in question the accuracy of his observation. He claims to have seen the first cleavage-spindle in a vertical position, and that the first cleavage-plane takes place accordingly in a horizontal direction. Just after the division of the spindle, two nuclei were seen in the axis of the "Keim"; one lying in the floor near the vitellus, the other at some distance from this and directly above it. The subsequent division of the upper nucleus was accompanied by cleavage of the archiblast; but the division of the inferior nucleus was not attended by cleavage, and led simply to the formation of a multi-nucleated cell, the so-called parablast. The parablastic nuclei were seen in each of the subsequent stages of cleavage, and kept equal pace with the archi-

* Cf. Kupffer on Laichen und Entwicklungsgeschichte des Ostseeherings.

blastic nuclei in the process of division. Hoffmann admits that his observations are not complete, inasmuch as he was unable to follow the division of the first cleavage-spindle, and did not even find a spindle formation for the original parablastic nucleus. His failure in these particulars is attributable to his method of employing strong acetic acid (five to ten per cent), which renders the germinal disc opaque so rapidly that one can get only uncertain glimpses of what is going on in the interior. Mounted preparations, or actual sections of these early stages, would have given pictures of a much more reliable character, which would have served to confirm or correct impressions obtained by the acetic acid method. After reading carefully Hoffmann's account of the initiatory cleavage, we find that the following questions have been left either unanswered or in uncertainty: —

(1.) Does the supposed horizontal cleavage take at first the form of a circular groove?

(2.) What are the form-changes which accompany this cleavage?

(3.) Does the vertical axis of the blastodisc lengthen or shorten during the process?

(4.) Can the primary periblastic nucleus be demonstrated either by actual sections or mounted preparations?

(5.) Can any parallel for such a cleavage be found in any other class of animals?

With reference to the first question we are told, — "Das Ei von *Scorpaena* ist, im Vergleich zu den gewöhnlichen Zellen immer eine sehr grosse Zelle, und es wird also eine geraume Zeit dauern, bevor die Furche, welche alsbald Archiblast und Parablast von einander scheiden soll, so tief vorgedrungen ist, dass wirklich völlige Trennung beider Stücke folgt. *Bevor es hierzu kommt, hat sich der erste Kern des Archiblast, und wie mir höchst wahrscheinlich ist, auch der des Parablast, schon wieder in eine neue Spindel umgebildet.*"

Neither the figures nor the descriptions give us any very definite idea of the time or the manner in which this remarkable cleavage takes place. About the time the two primary nuclei (one of the archiblast, the other of the parablast) appear, we are informed that the blastodisc changes from a bi-convex to a plano-convex form; but whether this change accompanies the division of the first cleavage-spindle, or follows it, is left entirely to conjecture. Certainly there is nothing in such a change which would imply a lengthening of the vertical axis of the blastodisc; nor does it follow with certainty that the axis shortens. There is then, confessedly, a great deal of uncertainty in regard not only to details, but also to some of the more important

features of this supposed horizontal cleavage; and Hoffmann will probably agree with us that the *circumstantial* evidence ought to be more complete, before we concede such a fundamental difference in development between closely allied fishes.

If, however, it be claimed that Hoffmann's figures furnish conclusive evidence of his view, we shall have to admit that the first appearances favor this claim; but a somewhat closer examination of the text and the figures leaves a very different impression. A fair presentation of the question at issue compels us to call attention to Hoffmann's Plate IV. Figs 1–4, and the explanation of the same as given in the Tafel-Erklärung (p. 165) and in the text (p. 106). As it does not comport with the purpose and limits of this paper to give a complete historical sketch of his observations on the origin and development of the periblastic layer, we have selected for examination the plate which most fairly represents the grounds of his view.

Hoffmann states, in a very plain and direct manner, that Fig. 1 (Plate IV.) represents a 2-cell stage of his archiblast; we think this is what we have called the 4-cell stage, but cannot affirm this positively. It is also explicitly asserted that Fig. 2 represents a 4-cell stage (of the archiblast). Now this is assuredly an error. There are only two stages in the whole development which could give a view approximating that seen in this figure; namely, the 8-cell and the 16-cell stage. As this figure is only *about* five minutes later than Fig. 1, according to the explanation on page 165, it is quite impossible that Fig. 1 should represent anything earlier than our 4-cell stage. The next statement is certainly astounding; for it declares that Fig. 3 represents the 8-cell stage (we are speaking of the "archiblast"). We can assert with well-founded assurance that this figure cannot be said to represent any stage earlier than the 32-cell stage. The climax is reached in the twice-repeated statement (pp. 106, 165) that Fig. 4 represents a stage in which the "archiblast" is composed of 16 cells. Comment is unnecessary. Allowing that, as inadvertencies, these statements do not completely invalidate the figures, it may still be fairly claimed that they raise grave doubts as to the accuracy of Hoffmann's interpretation; and that they furnish us with a good reason for setting aside this interpretation, provided we can replace it with one that is more satisfactory.

We regard Fig. 1 as a 4-cell stage seen somewhat obliquely, so that two nuclei appear below the other two, as if they were in a subjacent stratum of protoplasm. The figure is illusory, and gives no idea of the relation of the blastodisc and the periblast at this stage.

Fig. 2 can be best explained as an 8-cell stage, in which one of the misplaced nuclei escaped notice. The inclination of the axis of the ovum and the method of treatment account for the illusive appearances and the failure to discover any continuity between blastodisc and periblast.

Fig. 3 is probably a 32-cell stage (it cannot be earlier). It represents four amphiasters belonging to marginal cells as if they were in a median plane.

Figs. 4, 5, and 6 combine surface views with optical sections. They become perfectly intelligible the moment we recognize the fact that the nuclei seen beneath the blastodisc occupy an entirely unnatural position. Their true position is superficial, near the margin of the blastodisc. These nuclei are undoubtedly true periblastic nuclei in Figs. 5 and 6.

Figs. 7, 8, and 9 of the same plate represent stages in the division of the *first* cleavage-spindle. Fig. 7 of this plate corresponds very nearly, if not exactly, to Fig. 3 of Plate III., the latter being another of those perspective figures with the perspective left out.

Fig. 10 is a puzzle: we know of no stage in the normal development of the teleostean ovum that would present *three* cells in an optical section.

According to Hoffmann's view, Fig. 7 ought to present two parallel amphiasters. His explanation of the omission of the hypothetical inferior amphiaster is, that, owing to its more central position, it could not be distinctly seen. Our view would account for its omission on entirely different grounds.

Hoffmann repeatedly calls attention to the fact that his "parablastic" nuclei keep an exactly even pace with the "archiblastic" nuclei in the process of division. This accords with our interpretation of Figs. 1 and 2; for in these early stages all the nuclei divide synchronously.

The Origin of Periblastic Cells. — With the 16-cell stage before described begins a most interesting chapter in the history of the periblast. Reserving a detailed description of the cleavage for the later and full account of our observations, we may here confine our attention to the more important events of this history. The virtual equator of the ovum, as we have said, lies in the marginal cells of the blastodisc, and may be supposed to coincide very nearly with the plane of division of these cells, as seen in Fig. 2. The peripheral half of these cells contains the larger part of the material which, at the outset, formed part of the periblast. Approximately speaking,

this half, together with the adjoining periblast, constitutes the entodermic hemisphere of the ovum. The difference of constitution between the marginal and the central cells, which is brought out by a differential staining, is manifest in sections, though not so decided as in later stages.

In passing to the 32-cell stage, the central portion of the blastodisc becomes two cells deep, each of the four cells *a*, *b*, *c*, *d* (Fig. 2) splitting horizontally, as shown by the vertical position of the amphiasters. The marginal cells divide obliquely, so that the outer half of each still remains in continuity with the periblast.

One hour after the 16-cell stage, we find the blastodisc three cells deep in the central portion; nearer the margin, two cells deep; and at the margin, one cell deep, as shown in Fig. 3.

At this time we find that the marginal cells, which are continuous at their outer and inner angles with the periblast, are still more strongly characterized than in the 16-cell stage. Their relations with the periblast are essentially the same. The central cells show the brownish tint characteristic of osmic acid staining, while the marginal cells are *much* lighter. In preparations stained with Grenacher's borax-carmine, the central cells take little or no carmine; but the marginal cells and the periblast stain well, thus bringing out a very decided contrast in color. This contrast in color extends to the nuclei, those of the central region being deeply browned, those of the marginal cells being stained red. The radial arrangement of the protoplasm around the nuclei is much more strongly accentuated in the marginal than in the central cells.

If the osmic acid is stronger, or is allowed to work longer than usual before transferring to the chrom-platinum solution, the contrast is often very much strengthened. In some of the mounted preparations, the central cells are very deep brown, almost black, while the marginal cells are light yellowish brown.

In most of the mounted preparations of this stage, the marginal cells appear to be well marked off from the periblast, although continuous with it; but we have one in which some of these cells have already entered the syncytial condition, which usually appears about two hours later. In this case they are considerably flatter than the marginal cell seen at the left in Fig. 3. But the syncytial condition is not yet fully established, coming and going as often as the cells divide.

Two hours after the 16-cell stage, the blastodisc is from two to four cells deep; and one or two marginal cells (in section) present the

characteristics before mentioned. At this time (Fig. 4) the surface cells, which are destined to form the epidermal layer, are more flattened than the deeper cells. It is not certain, however, that this layer is now *distinct* from the deeper cells. There are some very good grounds for thinking that some of the deeper cells eventually take a superficial position, assuming the flattened form.

Three hours after the 16-cell stage, we find a wreath of flattened cells encircling the blastodisc. Faint boundary lines are sometimes visible in the living ovum, but they soon disappear. Sections of the blastodisc at this time show that the wreath is composed of two concentric rows of cells, the inner of which lies beneath the margin of the cap, and hence is not easily seen in the living ovum. The inner row of cells is continuous with the thin periblastic floor of the cleavage-cavity; and the outer row is continuous with the larger external periblast. These cells (Fig. 5), derived from the marginal cells of preceding stages, are quite distinct from all others of this stage, if we except one or two usually seen above them; and, as they form the *Anlage* of the periblastic cell-layer, they may be called periblastic cells.

The one or more cells lying above the periblastic cells, which are also shaded in the figure, are less strongly individualized; but are, in many (not all) preparations, easily distinguished from the overlying cells. These cells, which we regard as the Anlage of the future entodermic layer, differ from the superjacent cells less than from the periblastic cells.

The periblastic cells multiply rapidly, the nuclei passing through the typical amphiastral phase at each division. As they increase in number, they spread in both directions, — inward, beneath the blastodisc, and outward, beyond the margin of the same, — thus forming the syncytial layer described by Kupffer, Van Beneden, Ryder, Hoffmann, and others.

When the entodermic ring begins to form (Fig. 6, *en*), we find that the periblastic nuclei have already spread far under the blastodisc. At this time there are no cell-boundaries around these nuclei, so far as can be ascertained from sections and mounted preparations. The periblast is now only a little thicker under the outer edge of the blastodisc than elsewhere; and no nuclei are found completely outside this thickened portion ("bourrelet périphérique," Van Bambeke).

The periblast then becomes a cellular layer as the result of one of the concluding acts of cleavage. The so-called "free nuclei"

neither arise *de novo*, nor from the division of the first cleavage-amphiaster, but in cells belonging to the margin of the blastodisc or blastoderm, which have at first well circumscribed boundaries. Some time before the embryonic ring appears, the inferior marginal cells flatten and form a wreath around the blastodisc. From this time onward these cells are entirely distinct from the blastoderm. Of their further history and significance something still remains to be said in the sequel.

It is hardly necessary here to call attention to the general importance of the discovery of the precise origin of this peculiar cell-layer, the history and meaning of which have so long been a standing puzzle, forming one of the greatest obstacles in the way of understanding the germ-layers of the vertebrates. We hope to be able to show later that this history is equally applicable to other meroblastic vertebrate ova.

The Order and Direction of Cleavage-planes. — The first four cleavage-acts, ending with the 16-cell stage, present some points of interest in addition to those already discussed under the head of "general remarks on the ovum." The direction of the first cleavage-plane is that of the axis of the ovum, whether this be vertical or not. When the ovum assumes its normal position of equilibrium, the axis is vertical, or nearly so, in the majority of cases; but this position is not universal, even among the teleostei. Gravitation of course influences the ovum as a whole, and may thus be said to control, *indirectly*, the directions of the cleavage-planes; but the idea that the first or any subsequent plane is vertical simply because this is the direction of gravitation, is in plain contradiction with the fact that cleavage-planes may form all possible angles with the vertical plane.

The *succession* of cleavage-planes, at least the earlier ones, in spite of all irregularities, presents a general uniformity or order. Is this order predetermined, *von vorn herein?* and how far is it allowable to speak of homologous cleavage-planes? The correspondence between the first cleavage-plane and the median plane of the embryo, which has already been ascertained in a considerable number of cases, favors the opinion that this cleavage-plane is homologous in at least all animals with bilateral symmetry. The evidence is, however, very far from being complete. It does not follow, because one cleavage-plane is homologous, that all the rest must be so. In comparing the teleostean and amphibian types of cleavage, we find no difficulty with the first two meridian planes of cleavage; but the homology of the third and of the fourth is not so obvious, while beyond this one would hardly venture to compare individual cleavage-planes. Rauber is the only

one who has undertaken a comprehensive comparison of these two types of cleavage;[48] and he was the first to show that variations in the cleavage of the frog's ovum occur which bring the two types together. While Balfour and others have supposed that the "equatorial" cleavage comes considerably later in the teleostean ovum than in the amplibian, and that therefore the *order* of the cleavage-planes is not the same in the two types, Rauber holds that they occur *only* in the latter, being replaced in the former by meridian cleavages ("Längsfurchen"). It is very rare, according to Rauber, that we have *true meridian* cleavages in the frog's ovum; the cleavage-planes usually called meridian do not seek the pole, but *shun* it. This is particularly true of the third and fourth meridian cleavages, the polar distance of which is often so great that they run nearly parallel to the first and second, presenting thus the teleostean pattern. According to this view, the third and fourth cleavage-planes of the teleostean ovum would correspond to the fourth and sixth of the frog's ovum, the two equatorial cleavages being skipped. The "Polflucht" theory of Rauber breaks the homology of the cleavage-planes between the second and third cleavage, and is in so far unsatisfactory. Balfour, in common with most authorities, has mistaken the first *concentric* cleavage, which occurs in passing from the 16-cell to the 32-cell stage, for the first equatorial cleavage.

We hold that the *order* of these cleavage-planes is identical in both types; and, accordingly, that the first, second, third, and fourth in the one correspond exactly to the first, second, third, and fourth in the other. "Polflucht" offers, to our thinking, no explanation of the origin of "parallel" cleavages in the ovum of the teleost. The real cause of an alternation from meridian to equatorial cleavage has never, so far as we know, been stated. The *equatorial* plane of cleavage is a *forced* one, and hence it *follows* the meridian cleavages. The meridian planes are the *natural* planes of cleavage; and the equatorial only a *dernier ressort*, introduced in accommodation to the elongated form of the blastomeres produced by meridian cleavage. The same is true of the concentric cleavages. The cell must elongate in order to divide; but it elongates in a vertical direction only when it is not free to do so horizontally. In the blastodisc of the fish ovum the necessity for a horizontal cleavage arises later than in the frog's ovum; and it naturally arises earlier in the central than in the marginal cells. The

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[48] Rauber. "Neue Grundlegungen zur Kenntniss der Zelle." Morph. Jahrb., VIII., pp. 255–335, 1882.

so-called "parallel" cleavages (the third and the fourth) are as truly *meridian* as the first and the second, using this term with reference to the individual blastomeres, not with reference to the entire ovum. There can be but little doubt that each blastomere, whatever be its position, elongates during its division *at right angles to its axis* (assuming of course that each has poles of its own); and if this be so, the difference between *meridian* and *equatorial* is one of name only. In other words, a plane which may be called equatorial to the entire ovum may be truly meridian to the individual blastomeres. In regarding the "parallel" grooves as meridian, not to the ovum, but to the blastomeres in which they occur, we have, it seems to us, an explanation of these grooves that is in perfect accord with what is now known in regard to cell-division, and escape the necessity of appealing to an unknown factor, such as Rauber has had recourse to. His "polflucht" theory, ingenious as it is, is built upon a hypothetical tendency or force (polar repulsion?), the existence of which is, in our opinion, much more than doubtful.

Irregularities of Cleavage. — The first cleavage splits the blastodisc into two equal, or sub-equal blastomeres; the second cleavage may likewise be equal or sub-equal. The third cleavage, which usually runs parallel to the first, dividing the blastodisc into eight blastomeres arranged in two parallel and equal rows, sometimes results in an oval instead of the usual rectangular form, in which one cell is central and seven are marginal. During the entire season we found but one case of this kind. The next cleavage gave five central and eleven marginal cells. The cleavage was not followed further, but the ovum developed into a perfectly normal embryo.

Another very interesting variation in the 8-cell stage was met with only twice. The third-cleavage planes were not parallel to the first plane, but meridian (not only to the blastomeres but to the ovum), resulting in an oval figure with radial symmetry. The next cleavage was concentric to the pole of the ovum. One of these was mounted and the other was lost, so that we are unable to say how such a variation would end. The ova were supposed to belong to Ctenolabrus.

On July 7 an ovum belonging to Ctenolabrus was found a few minutes before the formation of the first cleavage-amphiaster, and watched as far as the 16-cell stage. The first three cleavages were quite regular, but the position of the eight blastomeres was sufficiently different from the normal, to induce a very unusual form of the 16-cell stage. This stage presented *seven* central cells and nine marginal ones. The ovum developed a perfect embryo.

July 27, ova and spermatozoa of the Blackfish were mixed. The ova proved to be immature, the cleavage halting at the 8-cell stage. The interesting feature of the first cleavage was, that the two blastomeres at the close of the division assumed a perfectly circular outline, and separated so far that a distinct space was left between them. During the second cleavage, the two blastomeres came in contact, but did not flatten against each other, as they ordinarily do. The third cleavage was very feeble, and was not fully completed.

During the sixth division, which results in the 64-cell stage, we have noticed an irregularity of some importance. This irregularity occurred in the division of the central cells. We found that in some cases one or more floor cells divided horizontally, the upper cell taking a position among the superficial cells; in other cases, the reverse took place, some of the upper cells dividing horizontally, and giving cells to the floor layer. From such facts we may infer that there is no histological difference at this time between the upper and lower layer.

All these irregularities might be interpreted to favor the ideas recently advanced by Pflüger; but we cannot admit that they confirm some of his more extreme conclusions.

Other Cleavage Phenomena. — The *cleavage-folds* ("corona plicarum" of Max Schultze) are generally seen to best advantage during the first and second cleavage; but occur during the third, fourth, and even the fifth cleavage as well. These folds are of the same nature and appearance as those seen in the early stages of the frog's ovum. They are the "Faltenkranz" of Reichert. They may be regarded as an outward expression of the radial phenomena which accompany cleavage, as has been suggested by one [49] of us, and as maintained by Van Bambeke.[50]

Three classes of *vacuoles* are seen in our mounted preparations. The first are thin lenticular spaces, bounded by the cleavage-faces of contiguous blastomeres. These are few in number, and reappear in successive stages, particularly the earlier ones. These vacuole-like spaces are present in the living ovum. They are filled with a fluid which does not stain. The second class of vacuoles are small, round or semicircular, and arranged along either side of the external cleavage-lines. They are not found on the inner surface, nor at points intermediate between this and the outer surface. Their

[49] C. O. Whitman. "Embryology of Clepsine." Quart. Journ. Mic. Sc., 1878, p. 41.

[50] Ch. van Bambeke. "Nouvelles Recherches sur l'Embryologie des Batraciens." Arch. de Biol., I., p. 366, 1880.

arrangement gives the cleavage-lines a somewhat moniliform appearance. They are not seen in cleavage-grooves until the division is completed. They are unstained. We have not seen these in the living ovum, but think they may have been overlooked, as the blastodisc is usually seen from the inner surface, from which the vacuoles would not be easily recognized. A third class of small spherical vacuoles may be seen at different depths throughout the blastodisc.

Balfour found in the elasmobranch ovum vacuoles similar to the second class.[51] The presence of these vacuoles, he says, gives the cleavage-furrows a "beaded" appearance. "Their appearance is that of vacuoles, and with these they are probably to be compared. There can be little question that in the living germinal disc they are filled with fluid. In some cases, they are collected in very large numbers in the region of a furrow. Such a case as this is shown in Plate I. Fig. 6 *b*. In numerous other cases they occur, roughly speaking, alternately on each side of a furrow. Some furrows, though not many, are entirely destitute of these structures. *The character of their distribution renders it impossible to overlook the fact, that these vacuole-like bodies have important relations with the formation of the segmentation furrows.*"

The "spaltartiger Räume" described by Oellacher[52] differ widely in appearance and position from this class, but may nevertheless be of a similar nature. They appear, however, more like the "differentiated plane" which precedes and marks the course of a cleavage-groove. Flemming[53] has described and figured vacuoles much more closely resembling those we have described.

About the time the second cleavage begins, we find *minute opaque granules* along each side of the first plane of cleavage. These are most distinct and most numerous towards the extremities of the plane. At the deeper part of the groove, just where this stops and is replaced by the precleavage line above mentioned, the granules are arranged in two linear and parallel rows, one on each side the dividing line. At a somewhat higher focus, their arrangement is much less regular. These granules are neither abnormal nor artificial. As to their nature and origin, our preparations give us no definite information; but they are probably equivalent to the "cell-plate" of Strasburger and the thickenings of the "interzonal filaments" described by Mark (l. c., p. 231).

[51] Balfour. Development of Elasmobranch Fishes, p. 13.

[52] Oellacher. "Beiträge zur Entwicklungsgeschichte der Knochenfische." Zeitschr. f. Wiss. Zool., XXII., pp. 394, 395, 1872. (Pl. XXXIII. Fig. 22.)

[53] Flemming. Zellsubstanz, Kern und Zelltheilung.

Nuclei. — We have obtained a very nearly complete history of the nuclei as far as the 64-cell stage; but we have obtained this from mounted preparations of the blastodisc, which, on account of their thickness, do not admit of examination with very high powers. To this fact must be attributed our failure to analyze the various conditions assumed by the chromatic elements, with such detail and completeness as have been attained on more favorable objects by Flemming, Strasburger, and Van Beneden.

Contrary to what is seen in most of the figures of Flemming and Strasburger, the chromatine figures form only a minimal portion of the amphiasters. The first cleavage-nucleus is, in the living ovum, only .02 mm. in diameter. The amphiastral figure is always present before the outline of the nucleus is lost. The nucleus presents at first nearly a spherical form, then an oval form just before vanishing. Preparations of the nucleus in this oval or elliptical form usually show signs of division in the equatorial plane, which indicates that the chromatine fibres have already arranged themselves in two groups. At this time the precleavage plane is already established, and is coincident with the equatorial plane of the nucleus. About this time the nucleus becomes invisible in the living condition. The two nuclear plates move towards the opposite poles of the amphiaster, assuming a rounded contour just *before*, or at the moment of, reaching the edge of the polar areas. The polar areas, the centres of the asters, are irregular in outline, often amœboid in form, and stain very little or not at all. The spindle-fibres are very feeble, and scarcely distinguishable from the astral lines. The chromatic elements eventually reach the centres of the polar areas, but not until about the time these elongate to form a new generation of amphiasters. The astral lines are not lines in the strict sense of the word; for they appear to be made up of linear and somewhat fusiform elements, each having a radial direction, and thus producing the impression of radial lines. The spindle-fibres, in many cases, show a very feeble staining. The size of the achromatic polar areas forbids the idea that anything more than a small part of their substance is derived from the nucleus. Although the achromatic portion of the amphiaster appears to take the lead in the process of division, we are by no means certain that the chromatic elements do not play an *active* part. The extremely interesting investigations of Van Beneden[64] on the distribution of the chromatine in different

[64] E. van Beneden. "Recherches sur la Maturation de l'Œuf et la Fécondation." Arch. de Biol., IV., Parts 2 and 3, 1884.

phases of the nucleus, do not appear to support the opinion that the chromatine is merely passive food-material, as maintained by Brass.[55] The entire behavior of the chromatic elements during the process of division seems to be opposed to associating them with such passive material as food-yolk. The partial disappearance of chromatine in the nuclei of starved animals cannot be regarded as conclusive evidence that it is *surplus* nutritive material.

The early amphiastral divisions are very nearly synchronous; but it is rather rare to find the nuclei keeping equal pace sufficiently long to enable one to trace the exact genetic relationship of 64 blastomeres. We have obtained only a few preparations showing precisely 64 cells, and none containing exactly 128 cells. The periblastic nuclei, at the time when they first appear around the margin of the blastodisc, all divide nearly simultaneously, nearly all the amphiasters taking a radial direction.

The Cleavage-cavity. — Ryder has traced the history of the cleavage-cavity with much greater care and thoroughness than any other observer. He has not, however, given us the *early* history of this cavity. We have traced it from its beginning in the 4-cell stage up to the time when it becomes a spacious cavity, roofed by the expanding blastodisc and floored by the periblastic cell layer. During the cleavage stages it remains a very shallow cavity. Its outline, traced in Fig. 1, is quite distinct in most of our preparations and sections.

The Germ Layers.

The Periblast. — Among previous investigators, Rauber[48] has made the nearest approach to the discovery of the true origin of periblastic cells. His observations were made on hardened ova of Gobius, in which no periblast ("plasmodium") was found till towards the end of cleavage. At this time a differentiated ring of marginal cells ("Randschicht") was found, which were regarded, somewhat doubtfully, as the primary periblastic cells. The following remark will show how the case stood in his mind: —

"Die Centralzellen sind ihrerseits immer umsäumt von einer flachen Randschicht, als einem Rest der ursprünglichen Randschicht, von der sich neue Zellen abgeschnürt und den vier ersten Centralzellen bei gesellt haben. *Auf diese Weise kommt es bei Gobius, so viel ich aus*

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[55] Brass. Zool. Anz., VI., No. 156, p. 681, December, 1883; and Zeitschr. f. wiss. Mikroskopie, I., No. 1, pp. 39–51, 1884.

[48] Rauber, l. c., pp. 288–290.

meinem Material auf Grund von Schnittserien ersehen kann, zur Bildung jener Schicht, die als Plasmodium, Couche intermédiaire, sekundäres Entoderm, etc. bekannt ist. Eine vom Beginn der Furchung an als untere Keimschicht auftretende kernhaltige Protoplasmamasse, welche z. B. bei den Salmoniden so deutlich als Plasmodium des Keimes, oder sagen wir als primäres Entoderm auftritt, fehlt meinen Präparaten über Gobius."

Rauber appears to regard this mode of origin not only as doubtful, but as exceptional; for he straightway assents to the view maintained by Hoffmann, as true of teleostei in general, differing from him only in holding that the plasmodium is a part of the germinal disc, which from its destination, should be designated as "primary entoderm." The origin of the periblastic nuclei from marginal cells does not sustain Rauber's opinion in regard to the comparative rank of the plasmodium (l. c. pp. 300, 320).

Hoffmann maintains that the periblastic layer is separated from the blastodisc as the result of the first cleavage, and that it remains ever after distinct from it, taking no direct part in forming the embryo. In regard to its function, he comes to the conclusion, "in dieser Kernschicht die Werkstätte zu sehen, welche die Bestandtheile des Nahrungsdotters, des Parablast, assimiliret, um Zellen des Archiblast oder dem von ihm abstammenden Embryo in eine für die Ernährung geeignetere Form zu überreichen, mit anderen Worten, die an Kernen reiche Protoplasmaschicht des Parablast functionirt als *provisorisches Blut*."* This view of its function is however not wholly original with Hoffmann; for a similar idea had previously found expression in the writings of several embryologists, among whom may be mentioned Balfour and Klein, and more recently, but independently of Hoffmann's observations, Ryder, Kingsley, and Conn. Hoffmann states that the blastodisc grows during cleavage at the expense of nutritive material brought to it by the periblast, thereby overlooking the fact that it grows at the expense of the periblast itself.

With reference to the origin of the periblastic nuclei, Ryder[56] has suggested that the periblast may retain some portion of "the original nuclear matter of the egg," which may be the source of free nuclei in the yolk. In a recent paper[57] he has stated more at length his views on the function of the periblast, which he calls the "*yolk hypoblast*,"

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* l. c., pp. 136, 137.

[56] Ryder. Bull. U. S. Fish Com., I., p. 298, 1881.

[57] Ibid., II., pp. 183-187, 1882.

although contending that it forms no part of the real hypoblast. In former papers on the Spanish Mackerel and Silver Gar, he held to the opinion maintained by Kupffer and others, namely, that the periblast was truly hypoblastic: but finding no connection between it and the cells which form the alimentary tract, he concludes that it is only "a temporary and evanescent structure, which vanishes completely when the contained yolk material has been absorbed" (No. 57, p. 185), and that therefore it cannot properly be called "one of the primary embryonic layers."

In a recent paper (No. 21) Waldeyer has discussed at length the relations of the "archiblast" and the "parablast," claiming, in opposition to His, that they are one in origin. With reference to the origin of what we have called periblastic cells, he remarks (p. 31): "So far as my observations go, in thin sections of hardened preparations, nuclei, apparently free, are seen to appear in the pellicle of the teleostean ovum, as well as in the subgerminal yolk-layer, which multiply by division." The appearance of distinct cell limits around these nuclei at a comparatively late date, is defined as a "secondary cleavage." Speaking of the meroblastic ovum in a general way, he says: "The cleavage of the eggs of all those animals in which blood and connective tissue occur, is not uniform from beginning to end; but a *primary* and a *secondary* cleavage must be distinguished. The first divides the egg, so far as it is capable of cleavage, into a number of cells which are ripe for the formation of tissues. These form, then, the primary germ-layers. A remainder of unripe cleavage-cells (in holoblastic eggs), or of protoplasm which has not yet been transformed into cells (in meroblastic eggs), is left over." (pp. 47, 48.) A secondary cleavage later makes cells out of this remainder. "When the cleavage of the germinal disc is concluded, the pellicle [Rindenprotoplasma] and the subgerminal processes [Keimfortsätze] begin to break up into cells. These cells are smaller than those of the germinal disc, and naturally lie at first beneath the disc, especially beneath its margin, where they are imbedded in the white yolk, and also in the pellicle [Dotterrinde]. . . . . This process is very easily seen in the bony fishes, where it has often been described." (p. 15.)

With reference to the fate of the archiblast and the parablast, Waldeyer agrees, in the main, with His. He derives the blood and connective tissue from the "Rindenprotoplasma und aus den in den Dotter eingesenkten Protoplasmafortsätzen, den 'Keimfortsätzen,' wie ich sie genannt habe."

Kupffer, in his work on the Ostseehäring, also draws a sharp line

of distinction between "archiblast" and "parablast," based on the supposed "free origin" of the nuclei of the latter. He distinguishes two parts in the parablast, a "subgerminal plate" and a peripheral portion ("Rindenprotoplasma").

We have found nothing to justify the original parablast theory of His, nor can we accept the term "parablast" as defined by Kupffer, Klein, Hoffmann, or Waldeyer. The facts presented in this paper justify the opinion that the periblast represents a part of the entoderm. At the outset it is continuous with the blastodisc, into the margin of which it is progressively concentrated and thus brought under the direct action of cleavage. From the 16-cell stage onward it becomes more and more sharply differentiated, until at the conclusion of cleavage it takes the form of a wreath of flattened cells, destined to remain henceforth an independent layer. The nuclei of the cells multiply rapidly by so-called indirect division, and with each division the cells flatten, while their boundaries become less and less distinct. At length a thin nucleated "plasmodium," without any traces of cell limits around the nuclei, is formed. It is a veritable embryonic entoderm, the function of which begins and ends with the absorption of the yolk material. At least, we have thus far failed, as did Hoffmann and Ryder, to find any evidence that this layer shares in forming any portion of the permanent entoderm. From the time this layer becomes fully differentiated, it remains, at every stage, so perfectly distinct from every other portion of the embryo, that we see no ground for suspecting that it enters into any of the permanent embryonic layers.

The periblast is then a *true* yolk hypoblast, and is therefore, as Ryder hypothetically suggested, in all essential particulars, the homologue of the hypoblast of the yolk-sac of the chick. The chief difference between the bird and the teleost in this respect is, that in the former the periblast is continuous with the permanent entoderm, while in the latter its continuity is broken at a comparatively early date.

The Origin of the Entoderm. — On the question of the origin of the permanent entoderm of the teleost, the different views admit of being grouped into two great classes, according as they affirm or deny the participation of the periblast. Each of these classes may be subdivided into two: the first, according as the *whole* or a *part* of the entoderm is derived from the periblast; the second, according as the entoderm is said to arise by *delamination*, or by *invagination*, of the margin of the blastodisc.

The history of the origin of the entoderm, excluding the periblastic portion of it, is involved in that of the embryonic ring ("Randwulst," "Randzone," "Keimwulst," "Keimsaum"). We have given considerable attention to the formation and growth of this ring, with a view to obtaining an accurate idea of its composition and its relations to the embryo. Its mode of origin, composition, and history are the same in all the ova we have examined. Van Beneden, Hoffmann, and others, have insisted very strongly that this ring is not formed by a process of invagination. Balfour (No. 20, pp. 64–70) contends that there is no "true ingrowth or invagination of cells" in the elasmobranch development; and has devoted considerable space to an attempt to refute Haeckel's statements regarding such an invagination in teleostean development. On the other hand, Götte,[58] Haeckel (No. 3), Henneguy,[59] Kingsley, Conn, and Van Vleck, are very positive that the ring is formed by invagination, or ingrowth from the margin of the blastodisc; and we have satisfied ourselves that this view is essentially correct.

We do not affirm that any sharply delimited portion of the blastodisc is actually infolded; but we have *positive* proof that the ring arises as a centripetal *ingrowth* of cells from the margin of the disc. *Within one hour from the time the ring begins, the central area bounded by its inner edge is reduced to about one half its original extent, as shown by camera drawings of Ctenolabrus.* This fact furnishes indubitable evidence of the ingrowth, which has been so often denied and treated as incompatible with the facts of vertebrate embryology. A comparison of optical sections of the blastodisc, taken at short intervals during the formation of the ring, tells the same story. Actual sections simply furnish a verification of observations made on the living ovum. Precisely as was first shown by Götte, we find the ingrowing layer bending at the margin into the ectodermic layer. "Nach beendigter Furchung," says Götte, "bilden die Zellen des Keimes eine linsenförmige Scheibe, welche in einer entsprechenden Vertiefung des Dotters ruht. Darauf verdünnt sich die Mitte des Keimes und löst sich vom Dotter, so dass zwischen beiden die Keimhöhle entsteht, *Dann schlägt sich der Rand des Keimes auf einer Seite nach unten um und breitet sich an der unteren Fläche des Keimes aus. Dasselbe*

[58] Götte. Berlin. medicin. Centralbl., pp. 404–406, No. 26, 1869; and Archiv f. mikr. Anat., IX., p. 679, 1873.

[59] Henneguy. Bull. Soc. Phil. de Paris, 1880 (extract in Ann. Mag. Nat. Hist., IV., 1880). Compt. Rend., XCV., pp. 1297–1299, 1882 (abstract in Journ. Roy. Micr. Soc., III., p. 190, April, 1883).

geschieht später an der übrigen Peripherie. So besteht der Keim aus zwei Schichten, welche im verdickten Rande zusammenhängen." This description of the Trout corresponds exactly with Haeckel's account of the development of the Gadoid ovum: "Jetzt folgt der höchst wichtige und interessante Vorgang, den ich als *Einstülpung* der *Blastula* auffasse und der zur Bildung der Gastrula führt (Fig. 63, 64). *Es schlägt sich nämlich der verdickte Saum der Keimscheibe, der 'Randwulst' oder das Properistom, nach innen um und eine dünne Zellenschicht wächst als directe Fortsetzung desselben, wie ein immer enger werdendes Diaphragma, in die Keimhöhle hinein.* Diese Zellenschicht ist das entstehende Entoderm." (p. 439.) In one respect this account is incorrect; for it represents the entoderm as spreading beneath the entire blastodisc and forming a floor to the cleavage-cavity. There is a plain rolling-under, or involution, as an initiatory step in the formation of the ring; but we believe that the process is, in the main, more correctly described as an *ingrowth*, due both to a rapid multiplication of the cells, and also to the centrifugal expansion of the ectoderm. The floor cells of the cleavage-cavity are entirely periblastic, and have nothing whatever to do with the ring. The inner edge of the ring represents the limit of the ingrowing layer, which is thus confined to a narrow arc, precisely as in the elasmobranchs, according to Balfour's statements.

As to the significance of this inflected growth of marginal cells, there is every reason to believe that it is fundamentally the same phenomenon that has been so often described in other groups of animals as accompanying the epibolic or circumcrescent expansion of the ectoderm: in short, it must be regarded as the equivalent of a gastrula invagination. There is, of course, no such wholesale invagination as supposed by Haeckel, nor is such an invagination a necessary consequence of the view that the ring is the homologue of the lip of the blastopore in Amphioxus. Regarded as an invagination, the process is an extreme abbreviation of that seen in Amphioxus, since it is limited to an arc that agrees very nearly in width with the embryo (exclusive of the yolk-sac). If we take into consideration the embryonic entoderm (periblast) as well as the involuted entodermic ring, it would then be perfectly correct to say that there is a *complete* ingrowth; for the periblastic cells begin to multiply centripetally shortly before the ring appears, and reach the centre of the floor of the cleavage-cavity a little after it is formed. Thus the periblastic portion of the entoderm can be said to participate in, and to form a part of, the general ingrowth of the entoderm. That this ingrowth

takes place *before* the circumcrescent growth of the blastoderm is half completed, must be accounted for on the same general grounds that we should account for the formation of the embryo *before* the closure of the blastopore. From this standpoint, the fact that the periblast accompanies the blastoderm around the yolk becomes comprehensible and reconcilable with our general interpretation.

The investigations of Götte make it sufficiently clear that a similar ingrowth is characteristic of other meroblastic ova; and, contrary to the statement of Balfour (l. c., p. 69), we are confident that the development of the amphibian and the elasmobranch ovum furnishes nothing incompatible with this fact. The counter arguments drawn from this source will be considered in the memoir that is to follow this paper.

The epidermal layer of the ectoderm takes no share whatever in the involution. The entoderm bends directly into the deeper layer of the ectoderm, as is shown in Fig. 6, and as has been stated by Hoffmann and Henneguy. But this point can only be determined by sections; and this accounts for the error into which Kingsley and Conn have fallen, in supposing that the epidermal layer alone is inflected (l. c., p. 201).

An optical section, coinciding with the future median plane of the embryo, a few moments after the first indications of the ring appear, shows that the involution is not equally strong at the two opposite points of the ring. At the posterior margin, the in-rolling portion presents a strongly voluted outline; while at the anterior border it is much more feebly expressed. As the ring widens centripetally, we notice that the posterior thicker portion flattens and thins out as it spreads inward to form the "embryonic shield." The inward growth of the ring is completed in about an hour at all points, except at the posterior border, where the "shield" still continues its centripetal growth. Very soon after the ingrowth, which we may call the entodermic ring, to distinguish it from the ectodermic portion of the embryonic ring, has fairly begun, it appears everywhere to be only one cell thick, except in the axial region of the shield, where we find it from two to four cells deep. During the second hour of the ring, the shield, which represents the anterior end of the embryo (the hind end being represented prospectively by the remainder of the ring), becomes considerably thinner and nearly doubles its axial length. At the end of this time, it is only about three cells thick where it bends into the ectoderm; and from this point it becomes gradually thinner towards its anterior free edge, where it is only one cell thick.

Three or four hours after the appearance of the ring, when the blastoderm covers about one third of the yolk, and the anterior end of the embryo has nearly reached the ectodermic pole, we may obtain a good view of the formation of the chorda. For this purpose the ovum is so placed that we can get an optical transverse section of the embryonic portion near the middle. At this point the entoderm is only one cell deep, and the formation of the chorda can be seen with the greatest ease. A median band of the entoderm becomes plainly cut off from the lateral portions by vertical and nearly parallel planes of division. This median band, which is perfectly flat and of even thickness with the lateral portions, is the Anlage of the chorda. Leaving the history of the chorda at this point, we have to inquire how the alimentary tract is formed. As the lateral portions of the entodermic layer thicken up, they divide into two strata: the lower stratum is one cell deep, and represents the so-called "secondary entoderm"; the upper, which is several cells thick, represents the mesodermic plates. The lower strata abut at first against the inferior angles of the chorda, but close up under the chorda somewhat later, thus forming a single layer of flattened cells. About the time the blastopore closes, a median strip of this layer, corresponding in width to the chorda, begins to thicken, soon becoming two or three cells deep. It is this thickened strip that gives rise to the alimentary tube. Precisely how the solid band is converted into a tube, we are not at present able to state.

Comparing the foregoing account with that given by O. Hertwig [60] in his last paper on the development of the mesoderm of the amphibia, one important difference is seen. Hertwig comes to the conclusion that his "Chordaentoblast" forms not only the chorda, but also the roof, of the alimentary canal, the lateral and ventral portions of the canal being derived from the "Darmentoblast." We think that what we have described as the *entodermic ring* corresponds to the *chorda-entoblast* of Rana; and it seems plausible that the periblast should correspond to the "Darmentoblast" ("yolk hypoblast of Scott and Osborn [61]). On this view we should expect the periblast to take some share in forming the alimentary canal, which cannot be admitted if our observations are correct. Hertwig's observations do not bring the development of Triton and Rana into agreement on this point; and until this is done, we cannot expect to see the differences between the teleostean and amphibian development fully reconciled. But as there

[60] O. Hertwig. Jena. Zeitschr., XVI., pp. 247–323, 1883.

[61] Scott and Osborn. Quart. Journ. Micr. Sci., XIX, 1879.

seems to be a fundamental agreement in the development of all telolecithal vertebrate ova with respect to the origin of the "chordaentoblast," better called invaginate entoderm, or "invaginate hypoblast" (Scott and Osborn), there is a strong presumption in favor of the opinion that a complete agreement will yet be found to exist in regard to the precise origin of all the cells concerned in the formation of the alimentary tube. It is difficult to believe that the yolk cells ("Darmentoblast") form the *whole* of the mesenteron in Triton, only a *part* of it in Rana, and *none* of it in the teleost. Hertwig's observations on Rana have compelled him to admit that the invaginate entoderm takes a prominent share in forming the mesenteron; and his figures appear to us not only to warrant this conclusion, but also to suggest even more. Indeed, we think that they lend some support to the opinion that the mesenteron is formed exclusively at the expense of the invaginate entoderm.

Our observations on the relation of the mesoderm to the entodermic ring are not sufficiently complete to call for separate consideration. So far as they go, they appear to support the view that the mesoderm arises as two lateral masses, separated from each other by chorda cells, and from the periblast by a stratum of cells which, after uniting beneath the chorda in the manner before stated, are destined to form the mesenteron.

Kupffer's Vesicle. — Although we have been able to trace the entire history of Kupffer's vesicle in several species of ova, its significance remains as complete a puzzle as ever. Balfour homologizes this vesicle with the terminal dilatation of the "post-anal gut" of the Elasmobranchii, without, however, assigning any grounds for his view. The history of the vesicle is, in many respects, so entirely different from that of the "caudal vesicle" of the elasmobranch embryo, that we do not feel ready to accept this interpretation. The interpretations which have been offered by Kupffer and Henneguy are still more unsatisfactory, and need not be considered here.

Kingsley and Conn were the first to give an accurate account of the origin of this vesicle (l. c., p. 208); but they give us no information in regard to its subsequent history, and almost no details of its origin and growth. As they have stated, the vesicle arises by the fusion or confluence of a cluster of granules ("globules"). These granules are at first few in number (2–4), more or less angular, quite dark, and not more than .002 mm. in diameter. In general appearance, they are not distinguishable from the scattered granules seen in other parts of the ovum. In Ctenolabrus they appear soon after the embryonic ring

passes the equator, when the length of the embryo is about four fifths of the diameter of the ovum. They increase in number, grow larger, coalesce by degrees, and finally blend in a single bubble-like vesicle in the course of five hours. This vesicle, .01 mm. or more in diameter, more than doubles its diameter in the next hour and a half; and, steadily expanding, attains its maximum dimensions by the time the blastopore closes. It is somewhat variable in size and shape, but seldom more than .03 mm. in diameter, which is less than one tenth the diameter of the caudal vesicle of the elasmobranch. During all this time it lies beneath the chorda and the entodermic stratum, and has no sort of relation with any tubular structure whatever. As the alimentary canal is not yet in existence, it is difficult to see how this vesicle can be the homologue of a dilatation which arises *in*, and has no existence *outside of*, the post-anal gut. Ventrally and laterally it is bounded by periblastic material, but it has no cellular envelope in the strict sense of the word.

Soon after the closure of the blastopore, the vesicle begins to grow smaller, completely disappearing in the course of six hours. It is during this waning period that it steps into relation with the posterior end of the entodermic tract, which as yet has no lumen in any part. We have followed this portion of its history several times in different species of ova, and have satisfied ourselves that it is everywhere the same. At the beginning of the wane, about one third of its surface may be said to be enveloped by the entodermic stratum. At this time this portion of its surface (upper hemisphere) is considerably flattened, so that the entodermic envelope is really a very shallow umbrella-like concavity. Its vertical diameter now lengthens, while its horizontal diameter shortens; at the same time the entodermic concavity deepens, and its margin begins to form a plain constriction around the equatorial zone of the vesicle. Gradually the lower uncovered hemisphere rises up into the cavity, the whole vesicle growing rapidly smaller, until only a remnant remains, which is everywhere, except *perhaps* a small portion of its lower pole, enveloped by the entodermic layer. This remnant of the vesicle keeps on diminishing in volume, without any important change in shape, until it finally vanishes altogether. We are not able to say with certainty that a lumen exists from this time onward in this portion of the alimentary tract, but think this probable.

The closing history of the vesicle has thus some analogy with that of the caudal vesicle of the elasmobranch; but we require more evidence before concluding that they are homologous structures.

Secondary Caudal Vesicles. — Soon after Kupffer's vesicle begins to decline, we generally find a variable number of much smaller vesicles making their appearance between it and the hind end of the embryo. These secondary vesicles lie beneath the embryo in a somewhat thickened portion of the periblast. These grow larger, probably by coalescing, and may often be seen just in front of the terminal descending portion of the alimentary canal, until the tail attains a length of a millimeter or more. Whether the contents of these vesicles may be regarded as identical with the contents of Kupffer's vesicle, or whether any genetic relation exists between the two, we are not prepared to say. The general appearance of the two classes of vesicles is the same; and, until we had traced the disappearance of Kupffer's vesicle, we naturally assumed that the secondary vesicles arose by division of the primary vesicle, or that several primary vesicles coexisted from the outset.

Neurenteric Canal. — A surface view of the nearly closed blastopore shows that the epidermal cells surrounding it are much elongated in a radial direction. If the embryo be so placed that the remnant of the blastopore is seen obliquely, it will be seen to form a funnel-like depression, from the deeper and narrower portion of which a more or less distinct streak may be traced completely through this part of the embryo, which terminates at or near the posterior boundary of Kupffer's vesicle. In some cases this streak presents the form of a linear canal bounded by epithelium-like cells. The lumen of the canal is reduced to a mere line. It is difficult to recognize distinct boundaries to the wall of the canal in living embryos; and our sections have not thus far given us a satisfactory view of its relations to the alimentary tract. As the caudal plate (Ryder) thickens up, the canal, or streak representing it, appears to travel backward, which may be explained by supposing that the portion of the ring lying behind it is actually carried forward in order to form the hind end of the embryo. That such a migration of cells takes place is not absolutely certain; but the evidence is in favor of it, and the previous relation of the ring to the embryo sustains this view. There is at no time any nearer approach to a true neurenteric canal than we have described.

The Formation of the Embryo. — Our conclusions respecting the nature of the process by which the embryonic ring becomes converted into the embryo are essentially the same as those of His and Rauber. The so-called differentiation theory of Balfour and others fails to give any satisfactory account of the relation of the two lateral halves of the embryo to the ring, and offers no explanation of the "marginal

notch" which is sometimes seen in the blastoderm of the chick. The objections to the concrescence theory have been considered by one of us elsewhere: they are mainly drawn from those forms in which the evidences of concrescence have been partially obliterated, or more or less completely disguised. In the case of the teleostei, it is well known that the entire ring is converted into the embryo; but the manner in which this is accomplished has been very differently understood by different embryologists. The posterior end of the embryo is regarded by Oellacher as a fixed point throughout, from which the embryo lengthens *forward;* while His, on the contrary, holds that the anterior end of the embryo represents rather the "fixed point" from which the embryo lengthens *backward*, by the concrescence of the two lateral halves of the embryonic ring. It appears quite certain to us that the *principle* of concrescence underlies the formation of the embryo. The concrescence appears under the disguised form of a migratory movement of the cells, which accompanies the epibolic growth of the blastoderm. The direction of the movement of the cells composing the ring is that of concrescent growth. We have obtained two embryos showing a very well marked marginal notch at the posterior end of the embryo, in the place of the usually single caudal lobe. This notch, in one case, lasted for more than an hour, but was eventually obliterated. In the case of Elecate, Ryder has stated that the metameric segmentation extends beyond the embryo to the ring itself, which appears to give very conclusive evidence of concrescent growth.

The Relation of the Median Plane of the Embryo to the First Plane of Cleavage. — We have found it rather difficult, except in a few unusually favorable instances, to determine the relation of the first cleavage-plane to the median plane of the embryo; but we have very satisfactory grounds for the conclusion that the two planes coincide. Roux and Pflüger came to the same conclusion in the case of the frog; while Rauber was led to think that the two planes cut each other at right angles. This coincidence appears to hold true in the case of Rhabditis, according to Götte's figures. In a paper that has just come to hand, E. van Beneden[62] makes the following remark on this point: "Le fait que chez les Ascidiens et probablement aussi chez d'autres animaux à symétrie bilatérale, le plan médian du corps de l'animal futur se marque dès le début de la segmentation justifie pleinement

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[62] E. van Beneden. "Recherches sur la Fécondation." Arch. de Biol., IV., fas. 3, p. 570.

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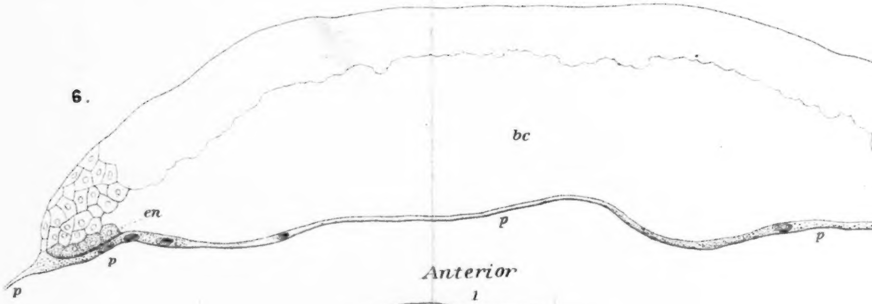

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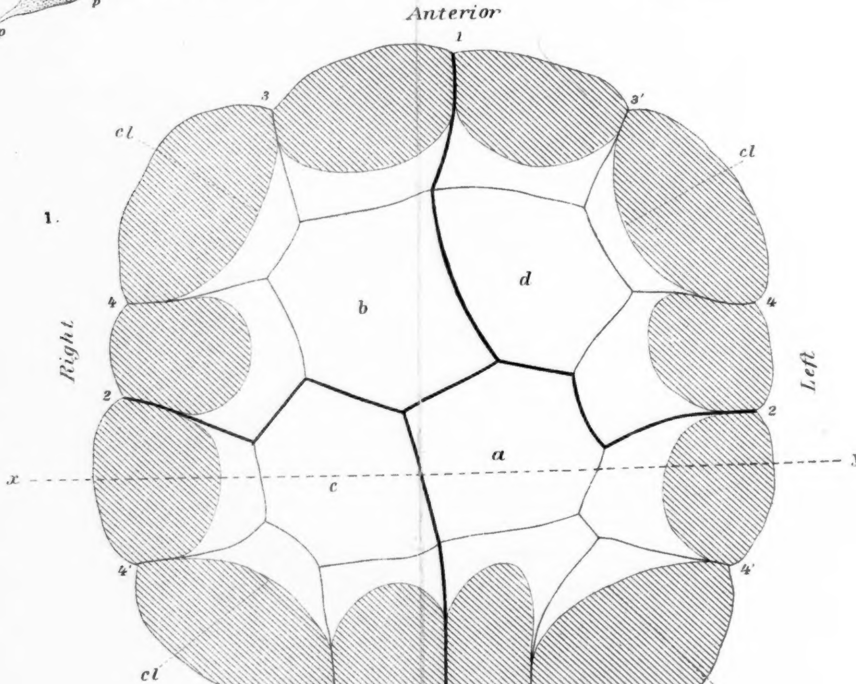

C.O. Whitman, del.

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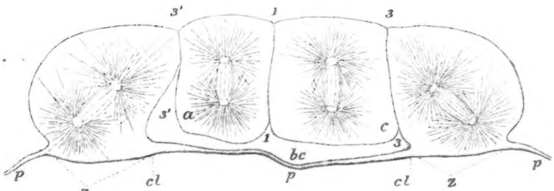

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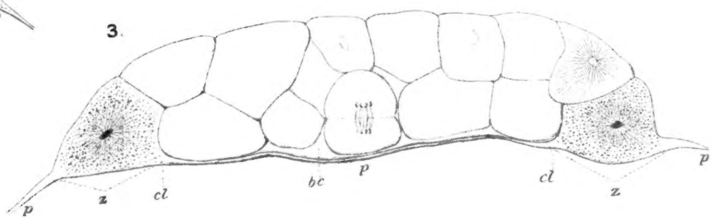

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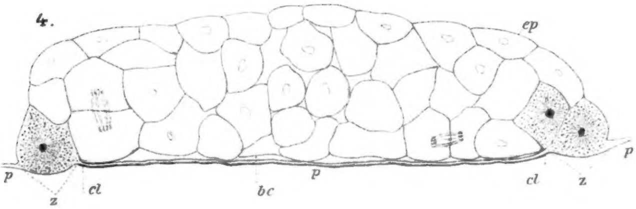

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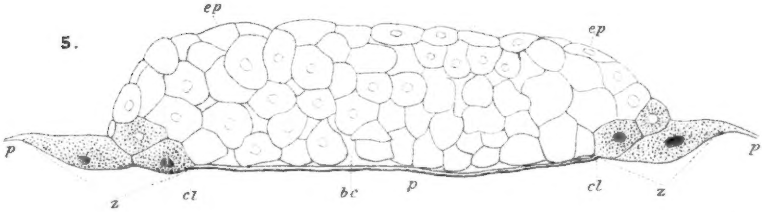


A. Meisel lith.

l'hypothèse d'après laquelle les matériaux destinés à fournir à la moitié droite du corps siègeraient dans l'un des hémisphères latéraux de l'œuf, tandis que l'hémisphère ovulaire gauche engendrerait tous les organes de la moitié gauche du corps."

If our ideas of the promorphological relations of the ovum are well founded, it will be seen that we have a very satisfactory foundation for the opinion, first suggested by Balfour (Comp. Emb., II., p. 312), that the neural surface is identical throughout the metazoa. It is hardly necessary to add, that this view is in perfect accord with the theory of concrescence before mentioned. Indeed, it is difficult to see how one can hold to the former, and deny the latter.

EXPLANATION OF FIGURES.

Figs. 1–5, *Ctenolabrus*. Fig. 6, *Ps. oblongus*.

All magnified 280 diameters.

Fig. 1. Blastodisc seen from the inner surface. The Arabic numerals give the order of the cleavage-planes; the shading indicates that portion of the floor of the marginal cells which rests on the yolk. *a, b, c, d*, central cells; *cl*, boundary of the cleavage-cavity; *xy*, plane of the vertical section seen in Fig. 2.

Fig. 2. Transverse section of the 16-cell stage, in the plane indicated by the dotted line (*xy*) in Fig. 1. *p*, periblast; *bc*, cleavage-cavity.

Fig. 3. Section of the blastodisc one hour after the 16-cell stage. The marginal cells are shaded.

Fig. 4. Two hours after the 16-cell stage. *ep*, epidermal layer.

Fig. 5. Three hours after the 16-cell stage. The marginal cells assuming the form of periblastic cells.

Fig. 6. Transverse section at the time when the entodermic ring appears. *en*, basis of the future entoderm.

V.

CONTRIBUTIONS FROM THE ZOÖLOGICAL LABORATORY OF THE MUSEUM OF COMPARATIVE ZOÖLOGY AT HARVARD COLLEGE.

No. IV.—THE EXTERNAL MORPHOLOGY OF THE LEECH.

By C. O. Whitman.

Communicated June 11th, 1884, by Alexander Agassiz.

There is no invertebrate animal about which more has been written than about the Medicinal Leech; but, as Dalyell long ago remarked, "it does not appear that the history of the leech has advanced in proportion to the number of the *literati* who have rendered it the subject of discussion." As a considerable share of the work done in this direction is purely systematic, it is somewhat surprising that not a single description of any Hirudo has been given with sufficient accuracy and completeness for a close comparison of even its more important external characters with those of other species. More than this, it would be impossible, from the many monographs, memoirs, and stray papers devoted to this subject, to patch up a description that would fully meet the requirements for a critical comparison of any two species. By far the greater number of species-diagnoses that have been showered upon us from time to time have been so superficially and slovenly done, that it would probably puzzle the perpetrators to identify the species they profess to have described. Some of the more important diagnostic characters have been either entirely ignored, or given with such vagueness that they are of little service in identification, and absolutely worthless for comparative purposes. No uniform mode of counting the rings has been adopted; and, judging from the descriptions themselves, systematic writers have, for the most part, failed to place much value on the rings in the determination of species and genera. No one appears to have suspected the existence of segmental sense-organs in the leech; much less the serial homology of the eyes with such organs. It is the object of this paper to make clear both these facts; and, at the same time, to show that the rings and somites form the only proper basis of classification. The latter fact will be brought out by a comparison of a few well-marked genera.

It is a well-known fact that the end somites are *incomplete* in respect to the *number* of rings composing them; but the mode and extent of abbreviation have not hitherto been made the subject of careful study; and hence some of the more important generic characters have been entirely overlooked, and with them some points of the highest morphological interest. Hirudo is the best known and most widely distributed genus, and on this account forms a convenient standard of comparison. As the arrangement of the segmental sense-organs enables us to determine the exact number of somites composing the body, we may deal with this part of our subject first.

The Segmental Sense-organs of the Leech. — The only sense-organs hitherto known in the Medicinal Leech are the five pairs of eyes and the so-called "goblet-shaped" organs located on the lip (cephalic lobe). A number of writers have noticed and described some small spots, occurring on every fifth ring of the body; and one author has suggested that they may have a respiratory function. These spots when examined closely with a low magnifying power will be found to be slight elevations with rounded summits; and for this reason, and because they are regularly disposed on the first ring of each somite, they may be called *segmental papillæ*, a name which does not prejudge the question of their function.

In our large Pond Leech (Macrobdella Verrill), these papillæ are comparatively small; and the same may be said of the medicinal leeches of Europe and Japan, and their nearest allies, Hæmopis and Aulostoma. In some of the Asiatic medicinal leeches, for example, those of Saigon, Singapore (*H. maculosa*), Java (*H. javanica*), and Ceylon (*H. multistriata*), they are much larger, and have an oval form, with a median ridge or crest. In the land leeches they are very conspicuous, having the form of small cones with rounded summits.

In all the ten-eyed leeches of Japan, including both the land and fresh-water forms, twelve of these papillæ are found on the first ring of each complete somite, six on the dorsal and six on the ventral side. In most of the medicinal leeches, however, as well as in Hæmopis, Aulostoma, Macrobdella, etc., there are eight on the dorsal side, and six on the ventral.

A careful study of the arrangement of these papillæ in a large number of species, and of their histological structure, has brought out in a most conclusive manner their serial homology with the eyes; and has led, indirectly, to the recognition of some important points in regard to the metameric composition of the body of the leech. The arrangement of the papillæ on the dorsal side is shown in Fig. 1.

The eyes are represented by five pairs of large black dots; the papillæ, by smaller dots. The numerals on the left of the diagram give the number of somites; those on the right, the number of the first ring of each somite. The position of the seventeen pairs of nephridial pores is shown by short dashes (1st *p* to 17th *p*). With the exception of the genital and nephridial pores, the diagram shows only what belongs to the dorsal side.

It will be seen that there are twenty-six transverse rows of papillæ, — one for each somite; and that, owing to their uniform and symmetrical arrangement, they form also *eight longitudinal rows*. We have *two median* rows (*m*) formed of twenty-five successive pairs; *four lateral* rows, an *inner* (*il*) and an *outer* (*ol*) on each side of the median line; and *two marginal* rows (*mg*). The first two eyes hold the position of a pair of median papillæ, while the remaining eyes replace as many *inner lateral* papillæ. About this correspondence in position there is not, in my opinion, any room for doubt. In the diagram the outer lateral and marginal papillæ are to be seen as far forward as the first eye-bearing ring, the marginal ones alone being absent on this ring; but in most species of Hirudo both of these rows of papillæ are very indistinct, or entirely absent on the first three eye-bearing rings. They are present in Aulostoma, and are very distinct in the large medicinal leeches of Saigon, Singapore, Java, and Ceylon.

The median rows of papillæ, if their position is not misleading, must be regarded as the metameric equivalents of the *first* pair of eyes; the inner lateral rows hold the same relation to the 2d, 3d, 4th, and 5th pairs of eyes. There is a possibility that the first pair of eyes are derivatives of the inner lateral papillæ, the median papillæ of this ring having been lost, and the eyes brought nearer together so as to stand in line with the median papillæ of the following somites. However, as all the papillæ have the same structure, there is no objection on this score to the opinion that the eyes are derived from both the median and the inner lateral papillæ.

The structure of the papillæ confirms the homology above indicated, if one feature alone be excepted. The eye of the leech, as is well known, is a cylindrical mass of cells, three or four times as long as wide. The central or axial portion is made up of peculiar large glassy cells, in general appearance entirely unlike the other cells of the body. What the peculiarities of these cells are cannot well be explained without illustrative drawings; but, for present purposes, it will be sufficient to say that each of these cells has a vacuole-like central space, which is probably filled with some kind of fluid. What-

ever this fluid may be, it is not stained by any of the dyes in common use. The protoplasm of these cells forms a thick peripheral layer, with a rounded thickening at one point, which projects into the vacuolar space. The very small nucleus is usually located near the base of the internal protuberance.

The axial portion, consisting of glassy cells, is enveloped by a thick layer of pigment on all sides except the external end. The epidermal cap covering these cells is convex and entirely free from pigment, forming thus a window-like opening into the black pigment-cup which holds the large clear cells. An optic nerve enters the eye near its deeper end, and runs along the axis for a larger portion of its length. It is probable that branches of the nerve connect with the clear cells; but precisely how has not been ascertained.

In sections of the segmental papillæ, we find all the elements of the eye, except the pigment. There is a branch of the lateral nerves that runs to each; and from four to six or more of those large glassy cells are found a little below the epidermal cap, which is convex and free from pigment. The absence of a pigment-cup holding the glassy cells makes it doubtfu whether the papillæ can be regarded as visual organs; but it does not, to my mind, weaken the evidence of their serial homology with the eyes.

It is generally found that the posterior eyes, especially the fifth pair, are smaller than those preceding them ; and I have noticed cases in which only a mere trace of pigment could be seen in one or both of the last pair of eyes. While it appears doubtful what the special function of the papillæ is, still the presence of large clear cells, precisely like those in the eye, situated just below the window-like opening in the surface pigment, and their obvious serial equivalence with the eyes, makes it not improbable that they represent incipient organs of vision.

Although the evidence appears to me conclusive that the eyes and the segmental papillæ were, originally, morphological as well as physiological equivalents, it does not, of course, follow necessarily that both organs now have the same functional significance. The original papillæ may have represented sense-organs of a more or less indifferent order, among which, in the course of the historical development of the leech, a division of labor was introduced, a few at the anterior end becoming specialized as light-perceiving organs, the rest either remaining in their early indifferent condition, or becoming specialized in some other direction.

The discovery that these papillæ are sense-organs might lead us to speculate on affinities of a distant and somewhat uncertain nature,

such as are supposed by the writer, in common with many others, to exist between annelid worms and vertebrates. At all events, the existence of such organs in the leech furnishes a broader basis for the discussion of the question, whether the vertebrates and annelids have been derived from a common form possessing metameric sense-organs, as was first argued by Dr. Eisig of the Naples Station. Assuming that the sense-organs of the lateral line of the vertebrate and the segmental papillæ of the leech may be traced to a common origin in some remote ancestral form, it does not follow that they should now present close structural resemblances. It is far more important to show that they possess certain general features in common. The most important of their common features is undoubtedly their metameric origin. The nerve-supply forms another feature of fundamental importance, in which, according to the interesting observations of Mr. Beard, on "the segmental sense-organs of the lateral line" (Zool. Anz., VII., Nos. 161 and 162) of the vertebrate, there is essential agreement. The developmental history of these lateral organs in the fish, where they make their first appearance as *segmental papillæ* in the strictest sense of these words, cannot at present be explained on a more satisfactory hypothesis.

The fact that the eyes of the leech are metameric sense-organs representing merely structurally improved forms of the segmental papillæ, will be placed in still clearer light by the following study of the abbreviated somites.

Hirudo and Allied Genera. — In order to arrive at satisfactory conclusions respecting the characters which distinguish the genus Hirudo from allied genera, we must make a thorough study of the rings and somites composing the body. The importance of this first step in a comparative study of genera will be seen as we proceed.

The obscurity that is supposed to exist in regard to the precise number of rings in the cephalic lobe and in the hind end of the body, affords no excuse for the meagre descriptions usually given of these regions; but furnishes rather an argument for describing them with the utmost care and detail. The difficulties in the way of counting the rings has been greatly overestimated. It is only necessary to adopt some method of counting that can be followed in the different genera. Some authors count the rings from the ventral side, beginning with the buccal ring (5th and 6th in my figure), and take no account of the rudimentary anal (or post-anal) ring: thus counted there would be only 95 rings, which is the number usually given for *Hirudo medicinalis* of Europe. According to another mode of counting, the rings are counted from both sides, but from two dif-

ferent points, so that the number corresponding to the dorsal half of a ring is not the same as that of the ventral half. Gratiolet, who was the first to emphasize the importance of a well-defined starting-point in counting, recommended the unconventional and extremely awkward method of beginning with the ring in which the last pair of nephridial pores is found, counting from this point forward. This is evidently an unnatural method, adopted under the persuasion that no more convenient fixed point could be found.

The simplest method, and the one least liable to confusion, seems to be that which I have followed in my diagrams, the first pair of eyes forming the starting-point. Each ring then has a definite number and precise relations, and homologous rings are easily recognized in different species. For reasons that will be made clear elsewhere by a comparison of different species, it is certain that the first three pairs of eyes in Hirudo mark three successive rings. Beginning with the first pair of eyes, we find the fourth and fifth pairs on the fifth and eighth rings respectively. This simple arrangement of the eyes, which is only slightly modified in the land leech (Hæmadipsa), holds good not only for Hirudo, but for Hæmopis, Aulostoma, Macrobdella, and all the more closely allied genera. From the fifth pair of eyes onward, the counting is rendered more easy by the size of the rings, and by the metameric arrangement of the color-markings and the papillæ.

It is certainly very desirable that species belonging to closely related genera should be described on a common plan; and I know of no better method than the one here proposed. It is quite certain that no well-marked ring exists in front of the first pair of eyes. There are here, to be sure, in some species, obscure traces of what, in the opinion of some observers, might be regarded as one or two rings. While it is important to take note of all such evidences of rudimentary rings, it is certainly advisable, for the sake of uniformity, to discard them in counting.

Figure 1 is designed to show all the important external characters which are typical of the genus Hirudo. The first ring of each somite bears the segmental papillæ, and their homologues, the eyes; the papillate rings, as we may call them, show us precisely how many somites are represented between the first pair of eyes and the posterior sucker (acetabulum). The papillæ on the sucker are not usually sufficiently distinct to form a reliable guide to the number of somites represented in this part, and may therefore be left out of account. The following definition of the genus Hirudo will serve as a convenient standard of comparison.

Every Hirudo has 26 *somites, counting from the first pair of eyes to the acetabulum:* 10 *of these — the first* 6 *and the last* 4 *— are abbreviated by the suppression of from* 2 *to* 4 *rings in each; and* 16, *lying between the first* (1*st p*) *and the last pair of nephridial pores* (17*th p*), *have each five rings. The* 6 *anterior somites include* 13 *rings, the first and second being represented each by a single ring, the third by* 2 *rings, and the fourth, fifth, and sixth, each by* 3 *rings. The* 4 *posterior somites embrace* 9 *rings* (94–102), *the twenty-third somite including* 3 *rings, and the twenty-fourth, twenty-fifth, and twenty-sixth, each* 2 *rings.*

The first ring of each somite is marked anteriorly, by a pair of eyes; and, from the 11*th ring onward, by the segmental papillæ, of which there are normally from* 6 *to* 8 *on the dorsal half of the ring, and* 6 *on the ventral half.*

The first pair of eyes replaces a pair of median papillæ; and the remaining four pairs of eyes replace as many pairs of the inner lateral papillæ (*il*).

The eye-bearing rings are the 1*st,* 2*d,* 3*d,* 5*th, and* 8*th.*

The buccals are the 5*th and* 6*th, which are united on the ventral side. The post-buccals are the* 7*th and* 8*th, also united ventrally.*

There are seventeen pairs of nephridial pores located in the hind edge of the ventral half of the following rings: — 13*th,* 18*th,* 23*d,* 28*th,* 33*d,* 38*th,* 43*d,* 48*th,* 53*d,* 58*th,* 63*d,* 68*th,* 73*d,* 78*th,* 83*d,* 88*th, and* 93*d. Each pair is thus in the last ring of its somite. Between the first* (1*st p*) *and the last* (17*th p*) *pair there are precisely* 16 *complete somites* (7–22 *inclusive*), *or* 80 *rings* (14–93 *inclusive*).

The male orifice lies between the 30*th and* 31*st rings, or the* 2*d and* 3*d rings of the* 10*th somite. The female orifice is* 5 *rings behind the male, between the* 35*th and* 36*th rings, or the* 2*d and* 3*d rings of the* 11*th somite.*

The clitellum includes the 9*th,* 10*th, and* 11*th somites.*

The anus lies in the 102*d ring, or between this and the preceding one.*

The other characters of this genus are based on internal organs, and are too well known to require repetition here.

We may now consider the abbreviated somites, and see what they have to tell us about the history and relationship of the ten-eyed leeches. We notice first of all that the abbreviation is greatest at the extreme ends, from which it is plain that it began at these points and progressed centripetally; i. e. towards the middle of the body. The first two somites have lost each 4 rings; the third, 3 rings; the fourth, fifth, and sixth, each 2 rings; making a total loss of 17 rings at this end. The twenty-third somite has lost 2 rings, and the

remaining three somites have lost 3 rings each, making a loss of 11 rings. This syncopation of 28 rings, at the two ends of the body, and at least as many more in the acetabulum, is not to be regarded as an actual loss; these rings have been sacrificed rather in the interest of the rings retained. The loss at the anterior end is correlated with a higher development of the sense-organs; at the posterior end, with a greater development of muscles. It is interesting to note that Natural Selection has played a part in deciding the fate of these rings; for the *papillate* rings have been preserved, while the non-papillate rings have been in part or wholly suppressed.

Is this suppression of rings still going on? or has it reached a limit? A closer examination of the rings in the terminal somites will show that the process of abbreviation is still advancing; and a comparison of different genera proves that its progress has not been everywhere equally rapid. The suppression of rings takes place by consolidation, two successive rings coalescing gradually. The papillate ring may unite with, or absorb, either the preceding or the following ring. In the Medicinal Leech, the 5th ring, which bears the fourth pair of eyes, is now in process of uniting with the 6th; while the 8th is absorbing the 7th. The evidence that these two rings are being swallowed up is seen, first of all, in the rings themselves; and secondly, in the different conditions which they present in different species. In Hirudo and several allied genera, the 6th and 7th rings are relatively narrow; and the grooves separating them from the 5th and 8th rings are obliterated on the ventral side, so that here the four rings appear as two. On the dorsal side they are still distinct, but not so deeply marked off from the 5th and 8th rings as from each other. The same process of consolidation is seen in Hæmopis, Aulostoma, and Hæmadipsa, but in slightly different stages. In Macrobdella all four rings are distinct on both sides; but the consolidation has already begun, as the grooves separating the 5th from the 6th, and the 7th from the 8th, are not so deep as the groove between the 6th and 7th, or as that between any two of the succeeding rings.

If centripetal abbreviation be the law of development, we should expect the 4th ring to disappear before the 6th and 7th. This course of events has already been realized in the land leeches (Fig. 2), in none of which is there a ring intervening between the third and fourth pairs of eyes.

Two non-papillate rings may also unite: an instance is seen in the 23d somite of Macrobdella, where the 2d and 3d rings (95th in Fig. 4) are wellnigh consolidated.

The elimination of rings has been carried farther in the acetabulum than in either of the posterior somites of the body. In a few species the papillæ have been well preserved on the disc; and in these cases their arrangement shows that papillate rings alone have been preserved in this region.

If the historical development of the leech has been marked by a progressive course of abbreviation, such as I have described, it is evident that an ancestral form must have existed in which the somites were more nearly alike from end to end. The embryonic development confirms this view, for in its earlier phases the somites form a chain of very nearly like parts. Later a few (7–8) of the posterior somites become constricted off and consolidated into the sucking disc. The somites at the anterior end are the first to arise, and hence the first to exhibit specialization. Among existing species, we find three in Japan which have departed less from the hypothetical ancestral form than has Hirudo. They agree with Hirudo in having 26 somites, but differ from it in having a larger number of complete somites. In each of these species we find only five abbreviated somites at the anterior end; but these five are abbreviated precisely as they are in Hirudo. The sixth somite embraces five rings, two more than the same somite in Hirudo. This difference explains other differences: for instance, the position of the first pair of nephridial pores in the 15th, instead of the 13th ring; and the position of the genital pores between the 32d and 33d, and between the 37th and 38th rings. If the difference in abbreviation is taken into account, it is seen that the nephridial pores and sexual orifices hold the same positions as in Hirudo. Passing to the posterior end of the body, we find that the 23d somite differs from that of Hirudo. In one species, *Microstoma pigrum*, this somite shows no plain evidence of abbreviation (Fig. 5); in another, *M. edentulum*, the 2d and 3d rings of this somite are often less plainly divided than the following rings; and in the third species, *M. acranulatum*, these two rings are as plainly consolidated, as in Macrobdella (Fig. 4). Thus one of these species has 18 complete somites; the second has 17 complete, and an 18th nearly so; the third has only 17 complete. The 24th, 25th, and 26th somites contain in each species the same number of rings as those of Hirudo. The 103d ring of *M. pigrum* (Fig. 5), which is the homologue of the 99th in Hirudo, shows signs of duplicity at its margins; and the 102d is constantly thicker than the preceding ring.

In the land leech, abbreviation has been carried farther at both ends than in Hirudo. The *number* of somites is the same in both

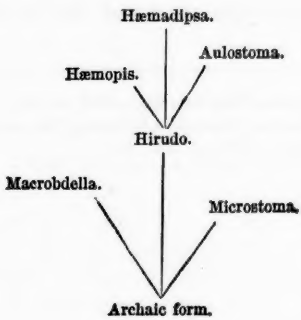
genera. The abbreviation at the anterior end is the same in both, except that the 4th ring of the aquatic leech has been dropped in the land leech. The loss of this ring brings the fourth pair of eyes into close order with the first three pairs, and the nephridial pores and sexual orifices one ring farther forward. At the posterior end (Fig. 3), we find only four rings at most to offset the last nine rings in Hirudo. The occurrence of segmental papillæ on each of these four rings, with perhaps the exception of the last, enables us to identify them, and to say precisely which rings have been lost since this leech abandoned its aquatic life. The rings may be identified as follows:—

93d ring	(Hæmadipsa)	=	94th ring	(Hirudo).	
94th "	"	=	97th "	"	
95th "	"	=	99th "	"	
96th "	"	=	101st "	"	

The lost rings are the 4th, 95th, 96th, 98th, 100th, and 102d.

Hæmopis is almost an exact copy of Hirudo in all the details of abbreviation; and scarcely deserves to be called a distinct genus. Aulostoma differs from Hirudo by a slightly less advanced abbreviation of its 23d somite, and in some other particulars that need not be mentioned here.

The degree of abbreviation is a key to the phylogenetic relationship of species and genera. The ten-eyed leeches have descended from a common form, having twenty-six somites, of which at least eighteen were complete. Of the genera mentioned in this paper, three may be said to have branched from the archaic form, Hirudo representing the main branch, and Macrobdella and Microstoma diverging branches. From Hirudo have arisen the three secondary branches, represented by Hæmadipsa, Hæmopis, and Aulostoma.



POSTSCRIPT.

In a very important paper dealing with the Hirudinea,* which came to hand only a few days before receiving the proof-sheets of the foregoing paper, Mr. Bourne calls attention to "sensory cells" found in *Hirudo medicinalis*. The following is all that is said on the subject: —

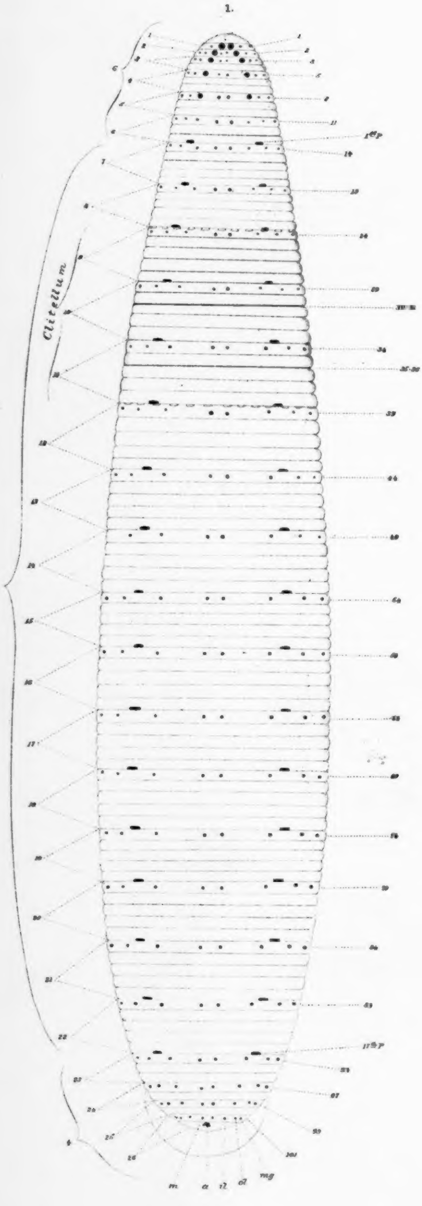
"I do not propose to do more here than draw attention to Fig. 15, from Hirudo, showing certain of these cells and their connections with nerve trunks. The preparation from which this is drawn was a section cut with a freezing microtome and stained in gold chloride.

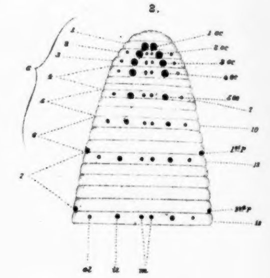
"My inability to say much upon this subject is the less to be regretted since Leydig † has dealt with these simpler tactile bodies and their derivatives, the eyes, in a most detailed manner."

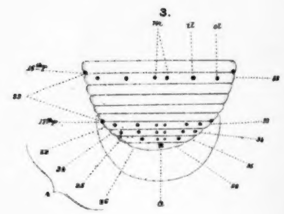
Unfortunately Mr. Bourne has not told us from what part of the leech his section was obtained, leaving it entirely uncertain whether it represents a part of a segmental papilla or one of the goblet-shaped organs on the head. As the figure shows none of those peculiar glassy cells, which are found in the eyes and segmental papillæ, it seems probable that it represents one of the simpler goblet-shaped organs which, according to Leydig, ‡ are scattered over the entire cephalic lobe.

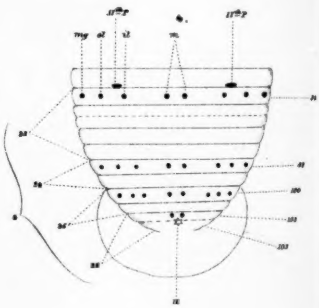
Mr. Bourne does not enter into any discussion upon the nature of the segmental papillæ, and their serial relationship with the eyes has entirely escaped his attention. The method adopted in determining the number of somites (by reference to the number of ganglia) is of course not reliable at the ends, where a fusion of primitively distinct ganglia has taken place. I have shown that the first thirteen rings constitute six abbreviated somites, while Bourne's method enables him to recognize only eight rings and two somites in the same region.

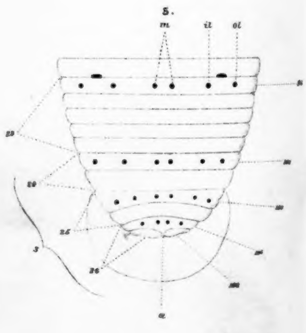
* Quart. Journ. Mic. Sci., July, 1884, p. 434.
† Vom Bau des thierischen Körpers, 1864, and Atlas.
‡ Müll. Arch., 1861, pp. 599, 600.











A. Meisel. Lith. Boston.

EXPLANATION OF FIGURES.

These diagrams are designed to show the serial relationship of the eyes and segmental papillæ, the abbreviation of the end somites, the relative positions of the sexual orifices, nephridial pores, papillæ, &c.

Fig. 1 illustrates these points in the Medicinal Leech.
Fig. 2 represents the first seven somites of the Land Leech (Hæmadipsa).
Fig. 3 shows the five posterior somites of the same.
Fig. 4 represents the posterior abbreviated somites of Macrobdella.
Fig. 5 represents the same somites in Microstoma.

The numerals on the left indicate the number of somites; those on the right mark the first ring of each somite. The eyes are indicated by large black dots; the segmental papillæ, by smaller dots; and the nephridial pores, by short dashes (1st–17th *p*).

1–5 *oc.*	The five pairs of eyes.
m.	Median papillæ.
il.	Inner lateral papillæ.
ol.	Outer lateral papillæ.
mg.	Marginal papillæ.
a.	Anus.
30–31.	Position of male orifice.
35–36.	Position of female orifice.

VI.

CONTRIBUTIONS FROM THE ZOÖLOGICAL LABORATORY OF THE MUSEUM OF COMPARATIVE ZOÖLOGY AT HARVARD COLLEGE.

No. VI.* — ON THE ANATOMY AND HISTOLOGY OF AULOPHORUS VAGUS.†

By Jacob Reighard.

Communicated June 11th, 1884, by Alexander Agassiz.

Material and Methods.

The material used in the preparation of the following paper was obtained from a ditch by the roadside near Fresh Pond, Cambridge, Mass., in October and November, 1883. In October the surface of the water was so thickly covered by a growth of Lemna as to be almost entirely hidden. Upon gathering the Lemna in a shallow dish, the worms could be easily collected by picking out the tubes which they had constructed from the Lemna leaves. Worms obtained in this way were easily kept all winter in glass jars containing water, in which some additional Lemna had also been placed. They lived and multiplied rapidly, even when not exposed to the sunlight.

For sectioning, the specimens were prepared by the use of either Kleinenberg's picro-sulphuric fluid, osmic acid, or chromic acid, good results being obtained with each. Borax-carmine, or a mixture of borax-carmine and picro-carmine as recommended by Bülow for Lumbriculus, was found to be the best staining fluid. The worms curl in a dorso-ventral plane in the killing fluid, but they may be straightened by placing them on a glass slide between the edges of two square cover-glasses, which are closely applied to the slide and held in position by wetting their under surfaces. The straightening is accomplished by sliding the cover-glasses against the worm, one on each side, care

* No. V. of these Contributions appeared in the Quart. Jour. Micr. Science, Vol. XXIV., N. S., 1884, under the title, "The Development of Phryganids, etc., by William Patten."

† Prepared under the supervision of Dr. E. L. Mark.

being taken not to crush it. This may be done by arranging two pieces of wire, of the diameter of the worm, so that their ends project between the edges of the cover-glasses. The glass slide may be laid for the purpose on a piece of wood, into which the other ends of the wires are fastened. After being straightened in this way, they may be rendered rigid enough for handling by placing on them while still between the cover-glasses a few drops of 70 per cent alcohol, in which they should remain for a minute or two. They are most readily handled by means of a pipette.

General Description and Habits.

Aulophorus vagus was named and described by Leidy in the American Naturalist for June, 1880, as follows: — "Our species I propose to name *Aulophorus vagus*. Body cylindrical, compressed, transparent, with red blood and yellowish-brown intestine. Single individuals of the third of an inch or more in length, composed of from 24 to 35 rings. Head ovoid, extending as a conical upper lip, very mobile and changeable in form, obtuse or sub-acute and minutely hirsute. Eyeless. Caudal ring contracted, and furnished with a pair of long, divergent, digit-like appendages, which are straight or slightly incurved, blunt, and minutely hirsute. Anal aperture surrounded by a rosette of half a dozen prominent, blunt, conical papillæ. The four rings succeeding the head furnished on each side with fascicles of seven to nine podal stylets; the succeeding rings, except the last, with fascicles of 5 to 6 podal stylets, which are shorter than the former. Podal stylets sigmoid with a median shoulder and ending in a furcate hook. The same posterior rings furnished dorso-laterally with fascicles consisting each of usually a single moderately long bristle and a single nearly straight stylet ending in a spade-like expansion. Pharynx capacious, going into the fifth ring, and narrowing into an œsophagus, which ends in the intestine within the ninth ring. Generative organs unobserved. Worm of 3 to 5 lines in length, or more, according to its degree of extension. Living in a tube of its own construction, which it drags about with it. The tube is composed of a transparent cement or basis, incorporated with various materials, such as vegetal particles, sand, dirt, diatoms, spongilla spicules, etc. In creeping about among aquatic plants, Lemna and Wolffia, the worm stretches in such a manner that one third of the body extends from the fore part of the tube, while the forked caudal extremity remains projected from the back end. The worm moves in jerks, alternately extending the fore part of the body and projecting the podal fascicles forward and hooking into

the surface on which it is creeping, and then contracting the fore part of the body and dragging along the back part enclosed within the tube. Frequently the motion is aided by eversion of the pharynx, so as to form a disc or sucker which adheres to surfaces like that of a leech. The movements occur in quick succession, so that the worm creeps about quite actively. At times it doubles itself, — thus passing through its tube and reversing its direction. At times, too, it will leave its tube and creep about without one. The papillæ of the anal aperture are clothed with vibratile cils, which produce an active current inwardly as observed in Dero."

The animals are found either single, or composed of 2 to 4 zoöids joined by bud-zones. In March, material kept over winter showed few specimens with bud-zones, and in the great majority of cases the number of segments was 25. The body tapers slightly posteriorly. It ends in an expanded pavilion resembling that described by Perrier for *Dero obtusa.* This pavilion (Pl. I. fig. 1, *pav.*) opens somewhat dorsally, and, when fully expanded, shows no trace of lobes on its dorsal and lateral borders. On its ventral border it presents in all cases two lobes, which are separated by a median notch and project slightly beyond the rest of the border of the pavilion. When the latter contracts, the dorsal and lateral borders become divided into four additional lobes by a median dorsal and two lateral notches. Thus, unless it is examined when fully expanded, the pavilion presents the appearance of "half a dozen prominent, blunt, conical papillæ" surrounding the anus, as described by Leidy. When the animal is in plenty of water, the posterior part of the body is habitually kept bent upward, so that the opening of the pavilion is toward the surface of the water. The digit-like appendages are attached laterally and ventrally, outside the border of the pavilion. Their outer ends are slightly swollen. They project directly backward parallel to one another when the pavilion is contracted; when it is expanded, they diverge. The number of podal stylets in each of the fascicles of the four anterior ventral pairs varies from 8 to 14, but they do not differ from one another at all, except in length, and this, taken in connection with the fact that they are fewer and more uniform in size in immature zoöids, gives no support to the notion advanced by Perrier ('72, p. 68) for *Dero obtusa*, that the fascicles are formed by the fusion of ventral and dorsal fascicles. The stylets in the ventral fascicles differ from those in the dorsal, and one would hardly expect this difference to be obliterated by a fusion of the two. The stylets in these four anterior pairs of ventral fascicles (Pl. I. fig. 2) are longer and straighter than those in the succeeding ventral

pairs. The fork on the convex side of the furcate outer end is much longer, sharper, more curved, and more slender than that on the concave side. The number of stylets in the ventral fascicles behind the fourth pair varies from 4 to 7, perhaps according to the age of the animal. They also vary in length. The fork on the convex side of the stylet (Pl. I. fig. 3) is very much smaller and sharper than that on the concave side, but not so long. These stylets are therefore readily distinguished from those in the first four pairs of ventral fascicles. The dorsal fascicles contain from 1 to 3 bristles, and from 1 to 3 spade-shaped stylets. The latter (Pl. I. fig. 4) are not so much curved as the ventral stylets. Their outer ends are flattened and expanded into thin triangular blades, one edge of the expanded portion being nearly straight, and the other concave, and both being strengthened by marginal ribs. A third rib sometimes runs midway between the two marginal ones. The bristles are much longer than the stylets, pointed, and without a median shoulder. The matrix cells of the stylets and bristles may be seen in sections. They have elliptical, granular nuclei, which are closely applied to the stylets and bristles.

In the fall, when the Lemna leaves were plenty, the tubes were formed entirely from them. Specimens kept over winter in glass jars in which there was but little Lemna formed their tubes entirely from Plumatella eggs, as described by Leidy. An isolated specimen in a small dish with some Œdogonium formed its tube entirely from the Œdogonium filaments. The worms were never observed to leave the tube voluntarily, nor were any ever found without a tube. When a single individual becomes divided into two, the two sometimes continue to occupy the same tube, one reversing its direction; or the newly-formed individual may build a new tube by the side of the old one and attached to it. An individual removed from its tube forms a new one in a very short time, frequently in less than ten minutes. The animal is easily driven from its tube by following it up from the posterior end with needles.

They stay most of the time at the surface of the water, and, when in a dish, usually at the side. There they lengthen their bodies, head downward, and seize the side of the dish by using the everted pharynx as a sucker. Then, by alternately shortening and lengthening the body, they continually move the tube up and down. The alimentary canal of the worms found at the surface of the water frequently contains a great many large air-bubbles, but such bubbles have never been seen in animals taken from the bottom of the jar. The bubbles are especially noticeable in specimens whose tubes are formed of

heavy material, and not of Lemna leaves nor Plumatella eggs. It would seem, then, that when its tube is heavy the animal has the habit of swallowing air-bubbles to keep it afloat. When driven from its tube, it swims about like a water-snake, but immediately seeks cover. Its food consists of diatoms and other unicellular Algæ and small water animals of every kind.

The only method of reproduction that I have observed is that by budding. No attempt has been made to determine the existence of a numerical law governing the budding process. The phenomena do not seem to differ from those described for related forms. In the sixth and seventh segments rounded cell-masses have been seen, which are probably the rudiments of the testes and ovaries, but they were never sufficiently developed to allow a satisfactory study of them.

Anatomy.

The Body Wall.

The body wall consists of four layers, in the following order, from without inward: a cuticula, the matrix of the cuticula or dermis, an annular muscular layer, and a longitudinal muscular layer.

The *cuticula* is a thin structureless membrane covering the entire surface of the body. It is easily seen in all sections, and may be demonstrated by leaving the animal for half an hour in a very weak chromic acid solution, or by using a very weak solution of potassium hydrate. Frequently, when the animal dies in water, the cuticula becomes raised up into vesicular swellings and is thus rendered plainly visible; when some part of the animal, as a digitiform appendage, is crushed, it then also shows plainly. The cuticula presents no markings under a power of six hundred diameters.

The matrix of the cuticula, the *dermis*, consists in most regions of a single layer of prismatic cells. The latter are, however, several layers deep on the frontal lobe. This layer is thicker at the head and tail ends, and in the region of the head and tail it is also thicker on the ventral than on the dorsal side. The dermal cells have large granular nuclei, the walls of which are frequently more distinct than those of the cells themselves. Each nucleus contains one or several nucleoli. The cells and their nuclei are longer in the head and tail regions than elsewhere.

Many unicellular dermal glands (Pl. II. figs. 11, 13, *drm. gl.*) are found in the region of the head, especially on the frontal lobe, and a few in the region of the pavilion. These glands vary in shape. Frequently

a tubular neck is seen leading to the surface, and a minute opening is sometimes visible. In sections the glands are seen to contain pale nuclei, usually near the bottom or on one side, and their contents appear granular and not stainable. They are very conspicuous on the frontal lobe in the living animal, and appear as sacs, sometimes slightly lobed, and always filled with rounded granules. When the animal is strongly compressed under a cover-glass, the contents of these glands are occasionally forced out through the neck. The nuclei have not been seen in the glands in the living animal.

The appendages of the dermis are the podal stylets, bristles, hairs, and cilia. The hairs are found over the whole body, but they are more numerous on the frontal lobe and on the digitiform appendages of the pavilion than elsewhere. They may possibly serve as sense organs. Cilia are found over the whole border and interior surface of the pavilion, and on the extreme front end of the pre-oral lobe.

The *muscular system* consists of a layer of annular fibres immediately beneath the dermis, and, still deeper, a layer of longitudinal fibres. There are also special muscles for moving the bristles, the pharynx, and the supra-œsophageal ganglion. Muscular fibres also help to form the partial partitions between the segments, and in the interseptal regions run from the body wall to the alimentary canal, suspending the latter. The fibres in the annular layer (Pl. II. figs. 11, 16, 17) are not so large as those in the longitudinal layer, and are seen with difficulty, but they show plainly in specimens that have been mounted for some time in balsam. The layer of longitudinal fibres is divided by the four rows of bristle sacs into four longitudinal bands, a dorsal, a ventral, and two lateral. These bands, as is easily seen in specimens mounted entire in balsam, are sharply marked off from one another by spaces that contain no longitudinal muscular fibres. Each band is divided into two secondary bands by spaces that contain no muscular fibres, or much fewer and narrower ones than are found elsewhere. This division into secondary bands is not always visible in specimens mounted entire, but is usually evident in such specimens near the posterior end of the body. In cross sections, however, this division becomes plain. The spaces between the halves of the lateral bands are occupied by the nervous lateral lines (Pl. II. fig. 17, *l. ln.*). The space dividing the ventral band lies immediately beneath the ventral nervous cord, and is the plainest of the four. This arrangement of longitudinal muscular bands agrees with that found by Perrier ('72, p. 72) in *Dero obtusa.*

The special muscular fibres for moving the pharynx and brain are

described in connection with those organs. The muscles for extruding the bristles do not differ from those described for related forms. Instances have been found, both in the living animal and in sections, of fibres running from a dorsal to a ventral bristle sac on the same side, and serving, doubtless, to retract the bristles.

The muscular fibres of both the annular and longitudinal layers are spindle-shaped and flattened. A few of them contain median swellings with large, granular central nuclei and nucleoli, while others have a small nucleus on the free edge, and therefore approach the muscular fibres of Nematodes in form. The cells of the bristle sacs, partitions, and all the special muscles, consist of a large central part containing a granular nucleus with its nucleolus, and of two or more processes arising from the central part.

The peculiar muscular cells found inside the digitiform appendages of the pavilion are described in connection with that organ.

Connective-Tissue Cells.

Connective-tissue cells (Pl. II. figs. 11, 16, 17, *cl'*.) are found in great abundance everywhere in the body cavity. They are of various sizes, being sometimes very large, and have deeply stainable, granular contents and nuclei with nucleoli. They vary in shape, but always have one or more long processes which are attached to surrounding parts. They are found in the greatest number above the pharynx, where they form an almost continuous mass, which connects the pharynx to the body walls above, thus helping to support it. These cells also line the body walls internally, and take part in the formation of the partitions. Many of them connect the alimentary canal and the nervous system to the body walls and to each other; and, in fact, they bind together all the internal organs. They form the external covering (neurilemma) of the nervous system, and also pass in between the ganglionic cells and the fibrous portion of the nervous substance, thus separating them. Whether or not they form the tissue that separates the nerve fibres from one another I have been unable to determine.

The Alimentary Canal.

The alimentary canal is a simple tube running through the axis of the body cavity, and held in place by numerous muscular fibres and connective-tissue cells from surrounding parts, in addition to the dissepiments. Its walls are composed of three layers: an internal cuticula, a layer of ciliated epithelial cells, and a membrana propria. To these may be added a very imperfect layer of annular muscular

fibres, and an equally imperfect layer of longitudinal fibres. The intestinal tract is divided into four distinct parts: a mouth cavity, a pharynx, an œsophagus, and an intestine.

When closed, the *mouth opening* (Pl. I. figs. 1, 6), which is situated on the ventral face of the first segment, has the shape of a brace (⏞) with its cusp directed forward. Numerous superficial grooves radiate from it, the largest of them passing forward from the centre of the opening, the cusp, in some cases extending almost to the anterior end of the pre-oral lobe.

The *mouth cavity* (Pl. II. fig. 11) extends from the mouth opening vertically upward to a point just beneath the supra-œsophageal ganglion, where it joins the pharynx. Sometimes it is slightly convex forward. Its walls consist of the internal cuticula, the layer of epithelial cells, and the membrana propria. So far as observed, its epithelial cells are not ciliate.

The *pharynx* (Pl. I. fig. 1; Pl. II. figs. 11, 14, 15, 16) extends horizontally backward from beneath the brain in the first segment to the partition between the fifth and sixth segments, where it passes into the œsophagus. Its greatest internal diameter occurs at about the middle of the second (first post-oral) segment, where, measured vertically, it is about three times that of the preceding and succeeding parts of the alimentary canal. From this point it tapers in both directions, but more rapidly forward. When seen in median longitudinal section (Pl. II. fig. 11) the cavity of the pharynx therefore appears to be somewhat spindle-shaped, though that is far from being its true form. This cavity is divided by two longitudinal folds, one projecting from each lateral wall, into an upper and an under chamber (Pl. II. figs. 14, 15, 16), as described by Bülow ('83, p. 71) for Lumbriculus. When the pharynx is in its natural position a cross section (Pl. II. figs. 14, 15) shows that the upper chamber is triangular, with the vertex of the triangle uppermost; while the lower one is elliptical or crescent-shaped with its long axis horizontal, and, when crescent-shaped, the concavity of the crescent uppermost. Sometimes a peculiarity of the lateral folds, attributable to the state of muscular contraction, causes the apical part of the triangular upper space to project on each side, and the whole upper chamber thus becomes T- or Y-shaped. The walls of the upper space are composed of the internal cuticula, the membrana propria, and a layer of much lengthened epithelial cells (Pl. II. figs. 11, 16, *e t'*.), the long axes of which are perpendicular to the surface of the pharynx. These cells have elliptical granular nuclei, situated at their deep ends, while their granular cell protoplasm is concentrated at their

free inner ends, which bear many short, thick, very active cilia. In sections the cilia are seen to be matted together into columnar masses, the real nature of which may be learned by a comparison of a large number of specimens. Among these cells are found a few (Pl. II. figs. 11, 16, *mc. gl.*) that are larger and have less granular and less stainable contents, and a smaller nucleus more centrally located. They are similar to the cells found by Nasse ('82, p. 15) in the same position in Tubifex. They were believed by him to be mucous glands (Schleimdrüsen).

The walls of the lower chamber have the cuticula and membrana propria, and a layer of much flattened epithelial cells. The latter are especially flattened in the anterior half of the pharynx, where the floor of the lower chamber is therefore very thin. No cilia have been observed on the walls of the lower chamber. Both longitudinal and circular muscular fibres are better developed on the pharynx than in any other region of the alimentary canal, as is plainly to be seen in sections. They do not by any means, however, form a continuous layer.

Muscular fibres (Pl. II. fig. 11, *mu.*) also arise from the extreme anterior wall of the first (head) segment, and are inserted into the pharynx just beneath the middle of the supra-œsophageal ganglion. These, with other fibres running obliquely downward from the walls of the mouth cavity to the body walls, both anteriorly and posteriorly, serve as protractors of the pharynx.

Covering and closely applied to the walls of the upper chamber of the pharynx are found a large number of peculiar, more or less rounded masses of cells (Pl. II. figs. 11, 16, *gl'.*). These masses, or clusters, are several cells deep, and lie in groups, the size of which is determined by the frequency and position of the muscular fibres and the processes from the connective-tissue cells above the pharynx. The cells composing these masses have granular contents, and their nuclei contain each only a single nucleolus. They are ellipsoidal in shape, and their inner ends are frequently prolonged into processes reaching toward the pharynx. Similar cells have been described by Nasse ('82, p. 15) in Tubifex. On account of their position, and of their being divided into groups, they are regarded by him as digestive glands. He saw no opening, however, leading from them into the alimentary canal. In two instances I have been able to trace a process from one of these cells passing through the layer of epithelial cells to the pharyngeal cavity. Hence it seems probable that all these cells open into the cavity of the pharynx; but whether they have a digestive function is still open to question.

The largest of the connective-tissue cells are found above the pha-

rynx. They are very deeply stainable, have many processes, and almost completely fill the space between the pharyngeal glands and the dorsal wall of the body.

Thus the pharynx forms a highly specialized organ. It is, moreover, in almost constant use for purposes of prehension. It is used both in seizing the food and in locomotion. When it is extruded, the mouth opening is rounded and the pharynx has a cylindrical form. The protrusion is initiated by the action of the protractor muscles already described, and completed by the pressure communicated through the fluids of the body to the walls of the partly extruded pharynx, when the body walls are forcibly contracted. When it is extruded, the strong vibratile cilia of its walls are easily seen. They must help to render the extruded pharynx of use as a sucking disc, a purpose to which the mucous glands are doubtless also subservient. When applied to any object, the extruded portion may be rendered concave on its outer surface by the action of the muscular fibres in its walls, and those which pass from it to the body walls above; thus it becomes an effective sucking-disc.

The *œsophagus* begins at the septum between the fifth and sixth segments, and ends at that between the eleventh and twelfth. A slight but sudden increase in the size of the tube separates it from that part of the pharynx which immediately precedes it. The presence of liver cells also marks its beginning. It is of uniform diameter until it reaches the ninth segment, although it may be somewhat convoluted. In the eighth, ninth, and tenth segments it is much swollen, while in the eleventh it is of the same diameter as in those preceding the enlargement.

It is marked off from the intestine following it by (1.) a sudden large increase in the size of the tube near the partition between the eleventh and twelfth segments; by (2.) a difference in the length of the cilia in the two parts; by (3.) a difference in the brown drops in the liver-cells of the two regions; by (4.) a difference between the epithelial cells, as may be seen in sections; and by (5.) the absence, in most cases, of epithelial glands in the œsophagus, and their presence in the intestine.

While the cilia of the œsophagus are so long as to almost fill its lumen, those in that part of the intestine immediately following it are very short, or perhaps in some cases entirely absent.

In a portion of the œsophagus, viz. in the enlargement of the ninth and tenth segments, the lining epithelium presents a peculiar appearance (Pl. II. fig. 17, *en′*.). It no longer exists in the form of a simple

layer; but, while the greater portion of the cells remain destitute of cilia, and form a more or less continuous layer next to the membrana propria, there are other, less numerous cells, which project far into the lumen of the canal and are richly ciliate at their free ends. They are of various shapes, the basal ends being often produced into two or more diverging processes, which thus give the ciliate cells the appearance of spanning one or more of the cells of the non-ciliate layer. Although in many instances they appear to arise from the free surfaces of the latter, it is only a deceptive appearance, since their processes really extend to the membrana propria. They are to be regarded as the effect of a differentiation which results in an increase in the amount of surface exposed to the aliment, and at the same time relegates to a few cells the function of propelling the food along the canal. This peculiarity serves as a ready means of distinction between œsophagus and intestine, and is most apparent in cross sections. Similar, but not identical cells have been observed by Timm ('83, p. 148) in *Nais elinguis.*

A few epithelial glands have been seen in the œsophagus in the ninth, tenth, and eleventh segments, but as a rule they are absent from the œsophagus, while abundant in the intestine.

The *intestine* extends from near the partition between the eleventh and twelfth segments to the anus. It is distinguished from the œsophagus by the characters mentioned above. The tube grows suddenly larger in the twelfth segment, and then gradually tapers to the anus, being slightly constricted at each partition in the fore part of its course. The part of it following the œsophagus has either very short cilia or none at all. Farther back the cilia become longer, and near the anus they almost fill the canal.

Many endodermal glands (Pl. III. fig. 28, *en. gl.*) are found scattered throughout the epithelium of the intestine. They are unicellular and jug-shaped, usually somewhat larger than the neighboring endodermic cells of the same region. Sometimes they appear empty, but usually they are filled with a granular non-stainable material, or contain a nodule of such substance near the centre. Each opens into the interior of the intestine by a narrow canal, which is frequently visible in sections.

The *liver cells* are lens-shaped, with a large nucleus containing a single nucleolus. They are closely applied by one of their broader surfaces to the wall of the alimentary canal, just outside the layer of blood-vessels with which the latter is immediately invested, and which can be well seen only in certain longitudinal sections. Over a part of

the intestine these cells are arranged in longitudinal bands, as if they covered the intestinal network of blood-vessels. They contain numerous golden-brown drops. In the posterior part of the intestine these drops are still present in the liver cells, but they are colorless. Over the anterior part of the intestine a few of these brown drops are to be found, which are much larger than those met with over the rest of the alimentary canal. They are here seen to have a distinct limiting envelope, which is frequently broken, so that the contents of the drop have escaped. In such cases it appears to be the envelope that gives color to the drop. No such marked distinction of parts is visible in the drops occupying the cells upon the rest of the intestine. Over the whole of the œsophagus, however, the drops are larger than elsewhere, and most of them show a limiting membrane; this is especially noticeable in the anterior part of the œsophagus. The transition in the size of the drops is gradual, and does not sharply mark off the œsophagus from the intestine.

Floating in the body cavity are found globular cells, which contain very numerous brown drops that are frequently large, and have a limiting membrane. These cells often become compacted together into large masses. Clear, globular "lymp-cells" are also found floating in the body cavity.

The Vascular System.

The vascular system consists of a dorsal and a ventral vessel, united by a plexus in the head and one in the region of the pavilion, and by numerous vessels surrounding the alimentary canal. The dorsal vessel is covered, except in the pharyngeal and part of the œsophageal region, by the liver cells, and is contractile, whereas the ventral vessel is free from liver cells, and is not contractile. In the eighth, ninth, and tenth segments these two vessels are united by lateral branches, which float freely in the body cavity, one on each side in each segment. Like the dorsal vessel, they are contractile. There are often found traces of a vascular network lying beneath the liver-cells of the intestine and also uniting the dorsal and ventral vessels; but owing to its being hidden by the liver-cells, I have been unable to trace it out satisfactorily.

The plexus uniting the two vessels in the head has been figured and minutely described by Perrier ('72, p. 79) for *Dero obtusa.* In mounted specimens the blood-vessels are rarely to be seen, and are never visible throughout their entire course, while in the living animal their observation is difficult, because they are invisible except when

distended with blood. Only at considerable intervals of time does the plexus in the head become entirely filled, and usually then for only a fraction of a second; so that it is difficult to map out the entire plexus in any one animal, especially as those animals that have the most vigorous circulation are also the ones that move most rapidly. But, from an examination of a large number of specimens, I am certain that the arrangement in the head region is as follows: the *dorsal vessel* passes forward to above the brain (Pl. I. fig. 6) and there bifurcates. The branches resulting from its bifurcation pass downward at the sides of the brain, and, bending backward, finally unite at a considerable distance behind the mouth to form the ventral vessel. Before bifurcating, however, it gives off three pairs of lateral branches. Of these three pairs, the most anterior is given off just behind the mouth (the position of which is indicated in the figure as though seen through the tissues of the head). Each one of this pair, after passing outward to near the margin of the head, bifurcates, one of its branches passing forward and the other backward, and both joining the recurrent branch of the same side which results from the bifurcation of the dorsal vessel. The other two pairs of branches given off by the dorsal vessel pass out laterally, and probably also join the recurrent branches just mentioned. Some specimens show many other smaller vessels, and there is always a more or less complicated anastomosis of vessels around the pharynx, joining the dorsal and ventral vessels. It is possible that all these vessels present individual variations of branching and arrangement.

In the posterior region (Pl. II. fig. 5) the ventral vessel passes backward to near the notch between the two lobes on the ventral border of the pavilion. There it bifurcates, one branch running to the right and the other to the left along the border of the pavilion. These two branches become united on the dorsal border of the pavilion, and thus form a complete ring around its margin. Each half of this marginal ring gives rise to two branches. Each of the smaller pair arises close to the ventral bifurcation, and, passing along the median edge of the small lobe on the ventral border of the pavilion, makes a curve outward in that lobe, and then passes forward to unite with the larger branch lying on the same side. The larger branches arise at nearly opposite points in the lateral portion of the marginal ring, and, quickly converging as they pass forward, unite in the median dorsal line to form the dorsal vessel. This form of plexus differs from that found in *Dero obtusa* only to the extent of the modification rendered necessary by the difference in the form of the pavilion.

The contractile branches uniting the dorsal and ventral vessels in

the eighth, ninth, and tenth segments present the most favorable opportunity for studying the contraction of the blood-vessels. When one of these vessels is distended, its walls are seen to contain large, prominent nuclei, evidently belonging to muscular elements (Pl. I. fig. 7). When contracted the muscular elements are seen to be much shortened and thickened. The walls of the vessels also show longitudinal and transverse striæ. The vessels contract rapidly and are distended much more slowly. Their contractions take place at different rates in different individuals, and under different conditions. The observed limits are 11 and 24 contractions per minute. Although the ventral vessel does not contract, its walls contain the muscular elements mentioned above, but in less number.

No trace of blood corpuscles is seen in the living animals, but in sections the blood-vessels are frequently found filled with a granular mass apparently containing many corpuscles. This appearance may be due, however, to the action of reagents on the blood.

The Respiratory Organs.

The function of respiration is performed, in great part at least, by the pavilion. This and the distribution of blood-vessels to it have been already described. It is thickly covered with cilia, which produce an inward current of water. It contains numerous branched muscular elements, so arranged as to cause it to contract and close. The digitiform appendages are hollow, their cavities being continuous with the general body cavity. Their walls (Pl. III. figs. 29, 30) are composed of a single layer of dermal cells covered by the cuticula, which is beset with hairs (not shown in the figure). The cavity of each appendage contains many branched muscular cells, the processes of which are attached to the walls of the appendage.

Respiration is doubtless also carried on through the richly-ciliated walls of the intestine, which are covered by a network of blood-vessels and bathed by a steady stream of water.

The Nervous System.

The nervous system consists, as in related forms, of (1.) a supra-œsophageal ganglion and (2.) two commissures joining this to (3.) the ventral cord. The first two parts make up the circum-œsophageal ring.

The supra-œsophageal ganglion, or *brain*, (Pl. II. figs. 11, 19, 20; Pl. III. figs. 21, 25–27,) is situated immediately above, and in front of, the point where the mouth cavity joins the pharynx, and is divided by a median superior and anterior fissure into lateral halves, each of

which is rudely spherical in shape. A bundle of muscle fibres (Pl. II. fig. 11, *b. mu.*) passes from its posterior face upward and backward to the body wall. This bundle, together with a few fibres passing from its anterior face upward and forward, serves to support the ganglion in place, and perhaps to move it slightly. The ganglion is composed of a central fibrous part, surrounded on all sides except the lower by a layer of nerve-cells from one to four cells deep. On the lower surface the fibrous part of the ganglion is exposed.

Bülow ('83, p. 75) has described six pairs of nerves arising from the corresponding ganglion and commissure in *Lumbriculus variegatus.* In Aulophorus I have found only four pairs, three from the ganglion, and one from the commissure. The first pair (Pl. II. fig. 19; Pl. III. fig. 26, n^1.) corresponds to the sense nerve of Bülow. Each arises from about the middle of the anterior face of its half of the ganglion, and passes to the extreme anterior end of the segment. It is there distributed to the body walls. In Lumbriculus, Bülow ('83, p. 75) describes a group of cells in the anterior end of the first segment. These cells constitute a so-called sense organ, and to them this nerve is distributed, and is therefore called by him a sense nerve. Cross sections of Aulophorus show apparently similar large cells in the same position, but longitudinal sections (compare Pl. II. fig. 11) show these to be nothing more than sections of the swollen parts of the muscular cells whose processes pass to the walls of the pharynx.

The second and third nerves from the supra-œsophageal ganglion (Pl. III. fig. 25, n^2, n^3) arise together, lower and farther from the median plane than the first nerve. A short distance from their origin they separate, one passing to the anterior walls of the segment, and the other to the upper lip and adjacent parts.

The fourth nerve (Pl. III. fig. 25, n^4) arises from the commissure and passes to the lower lip. No nerve has been found passing from the supra-œsophageal ganglion to the lateral line, nor has more than one been found to arise from the commissure.

The œsophageal commissures pass obliquely backward from the brain to the ventral cord in the anterior part of the first bristle-bearing segment. They are composed principally of fibrous nerve substance, but there are a few ganglionic cells on their surfaces, except for a short distance in the middle part of their course, where the nerve cells are entirely wanting.

The *ventral cord* passes backward from the point of union of the two commissures to the region of the pavilion, where it gradually merges into the terminal germ-zone (Pl. III. fig. 31). In cross sec-

tion it is roughly elliptical, or bluntly crescent-shaped, with the concavity up (Pl. II. figs. 16, 17; Pl. III. figs. 22–24). Its central part is fibrous, and has a median superior and a median inferior groove. Lying in the floor of the superior groove are the three "primitive nerve fibres" of Ratzel ("Röhrenfasern") which are claimed by Bülow ('83, p. 92) to be of mesodermic origin, and therefore not to be compared to the chorda dorsalis of vertebrates. A single "fibre" begins in the third segment, while farther back two smaller ones are added to it, one on each side. The three, continuing side by side without branching, remain of nearly uniform calibre until just before the posterior end of the ventral cord is reached, when they disappear. Through most of their course they appear to be simple empty tubes, but the middle and larger "fibre" shows slightly stainable contents in its extreme anterior and posterior ends. The inferior groove is filled throughout its course with ganglionic nerve cells, and this is the only part of the cord where the layer of nerve cells is unbroken. The fibrous central part of the cord swells slightly and gradually in the middle of each segment (Pl. I. fig. 10). Its upper surface is free from nerve cells throughout its entire length, whereas the rest of its surface is covered by a layer of them which varies from one to four cells in depth, and forms a series of ganglionic swellings. This ganglionic layer is thickest at the centre of the segment, where the fibrous part itself attains its greatest diameter. There is a very short space in the region of the partitions, where the ganglionic cells, except in the ventral groove, are wanting. Muscular fibres pass from the centre of each ganglion to the body walls on each side and to the alimentary canal above. The ganglionic matter of the first four bristle-bearing segments is fused together into one mass, with only a slight increase in size in the middle of each segment.

The ganglionic nerve cells are apolar, unipolar, or rarely bipolar, and polygonal in form. Their nuclei are very large, leaving only a narrow zone of cell protoplasm around them. In each nucleus there may be one or several nucleoli, which appear as bright granules. The processes of these cells are sometimes traceable for a long distance, and pass into the fibrous nerve substance.

The nervous system is invested by a neurilemma formed of connective-tissue cells, which also pass in between the ganglionic and fibrous elements, and separate them from one another. This separation is, however, not complete, nor is it always evident, though, for the sake of uniformity, it has been so represented in the figures.

The fibrous part of the nervous system is composed of fibres, each

of which is surrounded by a sheath, most likely of connective tissue. A similar structure was seen by Nasse ('82, p. 13) in Tubifex, and is known to exist in other worms and among the Gastropoda.

The *lateral lines* (Pl. II. fig. 17) consist of a few cells, occupying the longitudinal space at the middle of the side walls of the body, between the dorsal and ventral halves of the lateral band of longitudinal muscles. They are considered by Bülow ('83, p. 75) to be nervous in function, and their connection with the œsophageal commissures has been traced by Semper in the case of Nais, but in Aulophorus I have been unable to trace them as far forward as the region of the commissures.

Segmental Organs.

The segmental organs (Pl. I. fig. 8) correspond closely to the description given by Perrier for those of *Dero obtusa.* Each somite after the sixth or seventh contains a single pair, which begin in the preceding segment and open out through the ventral wall of their own somite. Each organ is a thick-walled tube whose interior is lined by short, fine, vibratile cilia. Its first portion, lying in the anterior of the two segments concerned, is an expanded funnel, the opening of which bears cilia which are much longer than those found elsewhere in the tube. After passing the dissepiment, to which it is attached, there is an elbow-shaped, glandular expansion of the tube. From this expansion the tube turns toward the opposite side of the body, and, rising vertically, makes many convolutions, at the same time becoming covered with an irregular granular concretion. Nuclei may be seen in parts of this granular matter, and at times whole cells are visible, so that it is really composed of rounded cells closely applied to the tube and covered with granular matter. Following this cell-covered portion of the tube is a convoluted portion like that following the glandular swelling. The tube finally ends in an expansion which opens to the outer world a little in front of the ventral fascicle of podal stylets.

Throughout its course the walls of the tube show transverse striæ. The cells covering a part of it possibly secrete the glutinous material that forms the basis of the tubes in which the animals live; but the presence of similar cells in related forms that do not build a tube is opposed to this view.

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EXPLANATION OF FIGURES.

The signification of the abbreviations used is as follows: —

ann. mu.	Annular muscle fibres.
an. o.	Anal orifice.
b.	Brain.
b. mu.	Muscles attached to *b.*
cil.	Columnar mass of cilia.
cl'.	Connective-tissue cells.
cta.	Cuticula.
dg. app.	Digitiform appendages.
drm.	Dermis.
drm. gl.	Dermal glands.
d. va.	Dorsal blood-vessel.
en'.	Peculiar entodermic cells.
en. cta.	Endodermic cuticula.
en. gl.	Endodermic glands.
e t'.	Epithelial cells of the walls of the upper pharyngeal chamber.
ex. of.	External orifice of segmental organ.
fbr. n.	Fibrous (?) nervous matter.
g. cl.	Mass of indifferent germ cells.
gl'.	Digestive (?) glands.
gn. n.	Ganglionic nervous matter.
hp.	Liver cells.
in.	Intestine.
i. of.	Internal orifice of segmental organ.
lg. mu.	Longitudinal muscles.
l. ln.	Lateral line.
mb. pa.	Membrana propria.
mc. gl.	Mucous glands.
mtx.	Matrix cells of the podal stylets.
mu.	Muscular fibre.
mu'.	Branched muscle cells.
n.	Nervous substance.
n^1.–n^4.	First to fourth pairs of nerves from the brain and circum-œsophageal commissure.
œ.	Œsophagus.
or.	Mouth.
pav.	Pavilion.
phx.	Pharynx.
pr. n.	"Primitive nerve fibres."
sg. o.	Segmental organ.
stl.	Podal stylets.
val.	Body wall.
v. stl.	Ventral podal stylets.
v. va.	Ventral blood-vessel.

Plate I.

Fig. 1. *Aulophorus vagus*, dorsal view. The actual length is indicated by the straight line at one side of the figure.

Fig. 2. Podal stylets, such as form the first four pairs of ventral fascicles.

Fig. 3. Podal stylets, such as occur in the ventral fascicles after the fourth pair.

Fig. 4. Fascicle of dorsal stylets and bristles.

Fig. 5. Diagram of the circulation in the pavilion, dorsal view.

Fig. 6. Diagram of circulation in the head, dorsal view.

Fig. 7. Blood-vessel: α, expanded; β, contracted.

Fig. 8. Segmental organ.

Fig. 9. Frontal section through the ventral part of the anterior end of body, showing the commissures and part of the ventral nervous cord.

Fig. 10. Frontal section through the ventral nervous cord.

Plate II.

Fig. 11. Sagittal section through the head and pharynx. *mu.*, muscle fibres used to protract the pharynx.

Fig. 12. Cells of the walls of the upper space of the pharynx.

Fig. 13. Dermal glands in the living animal.

Figs. 14, 15. Outlines of cross sections of the pharynx.

Fig. 16. Cross section of the pharynx.

Fig. 17. Cross section of the œsophagus at the 9th ring.

Fig. 18. Dermal cells.

Fig. 19. Frontal section through a lateral half of the brain.

Fig. 20. Cross section through a lateral half of the brain. *cl'.*, connective tissue forming the neurilemma.

Plate III.

Fig. 21. Isolated nerve cells from the brain.

Fig. 22. Cross section through the region of the bristle sacs.

Fig. 23. Cross section near a partition.

Fig. 24. Cross section near the region of the bristle sacs.

Fig. 25. Sagittal section through the brain and one commissure.

Fig. 26. Sagittal section through a lateral half of the brain.

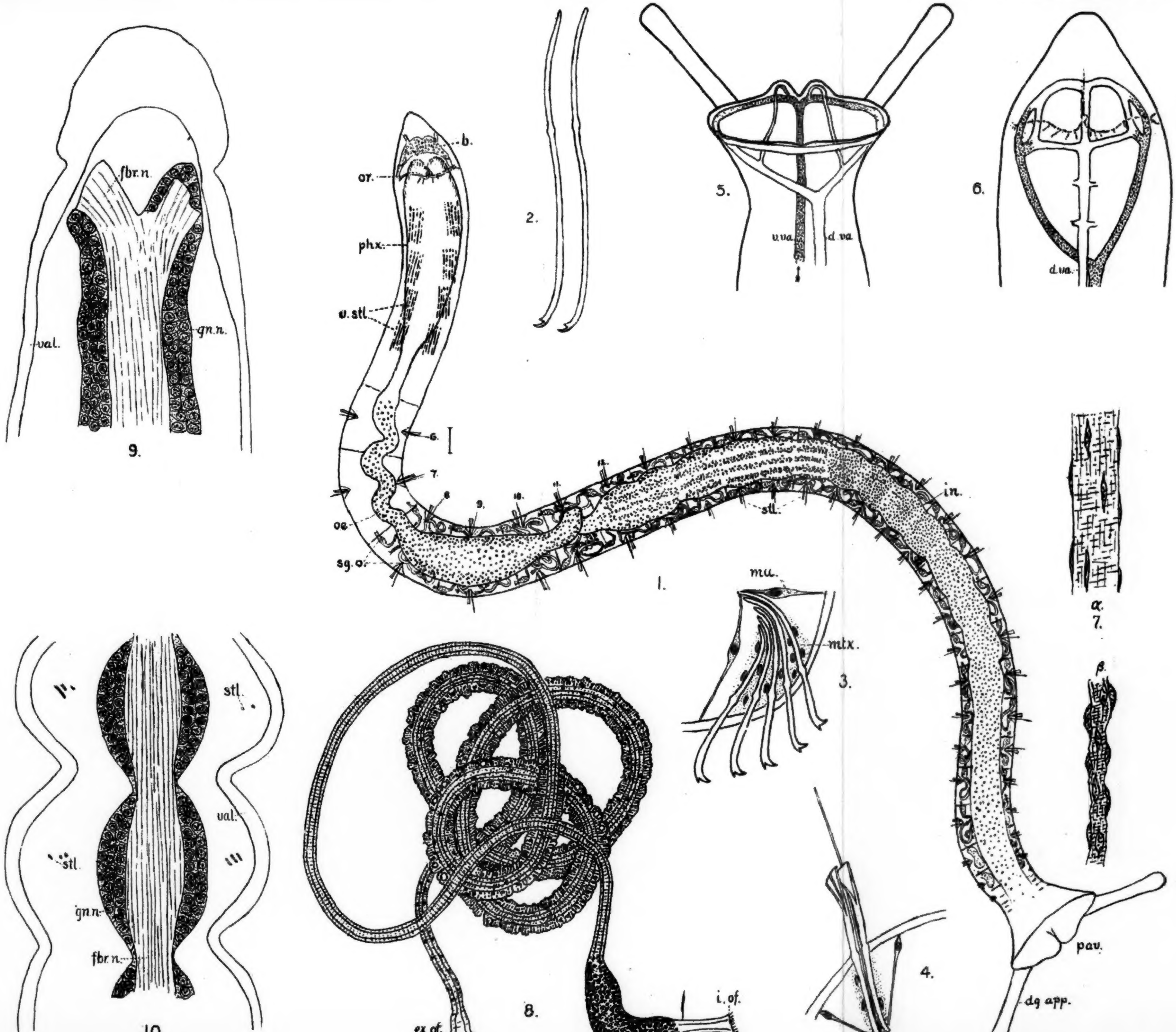
Fig. 27. Frontal section through the brain.

Fig. 28. Cross section of the intestine.

Fig. 29. Section cut obliquely through the region of the pavilion.

Fig. 30. Cross section of one of the digitiform appendages. *mu'.*, branched muscle cells.

Fig. 31. Sagittal section through the region of the pavilion, cut somewhat obliquely.



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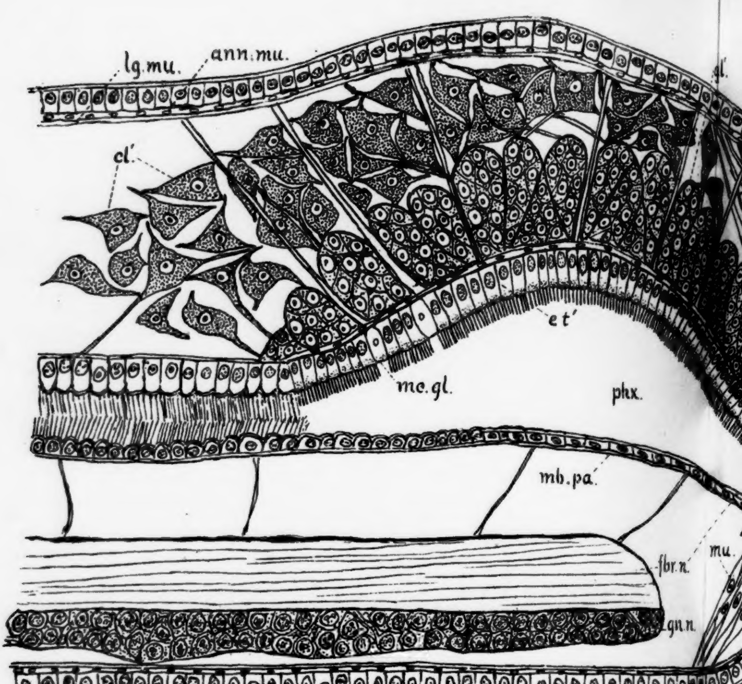

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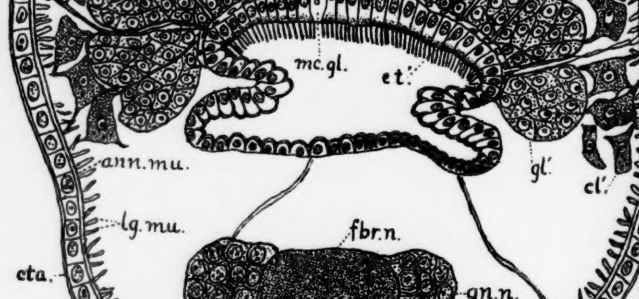

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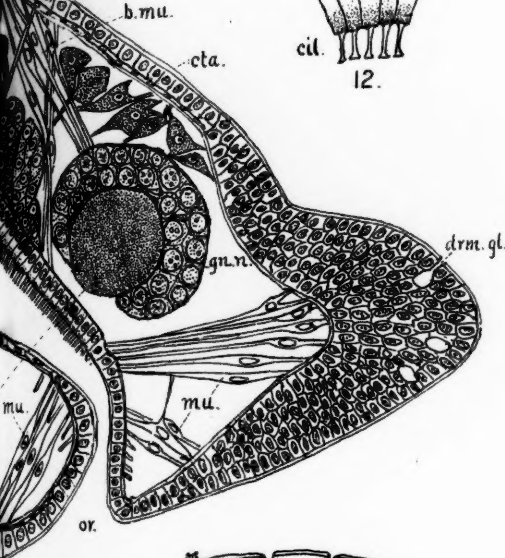

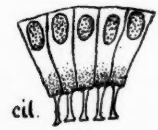

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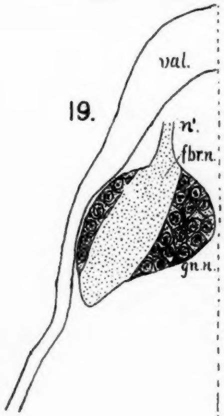

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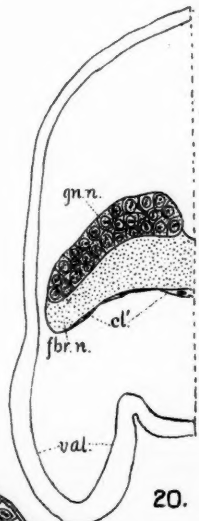

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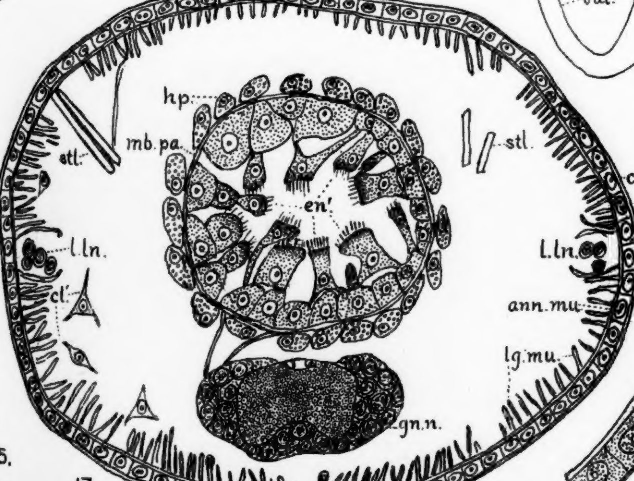

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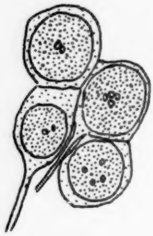

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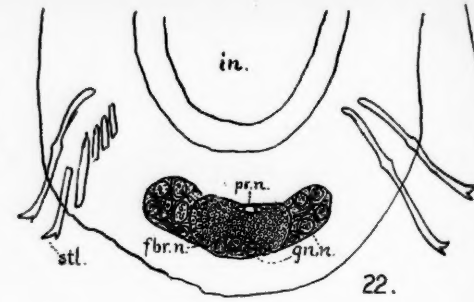

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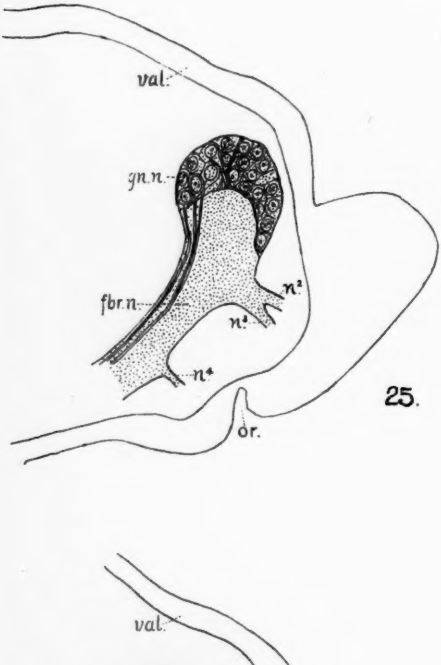

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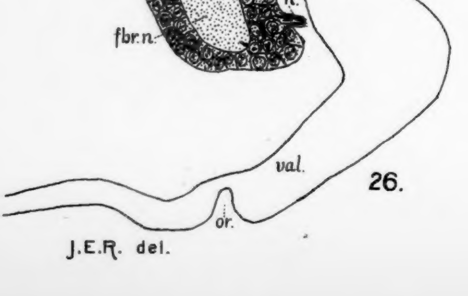

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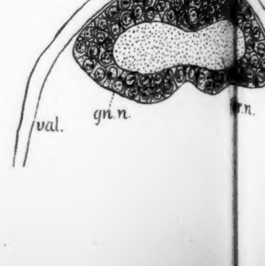

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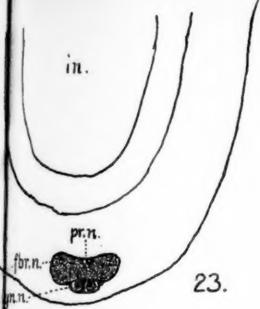

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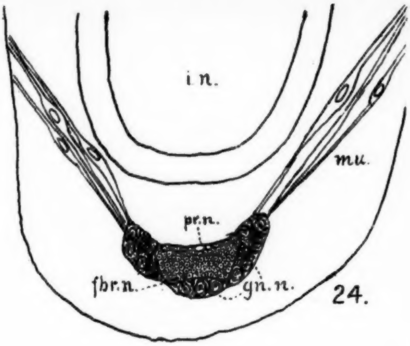

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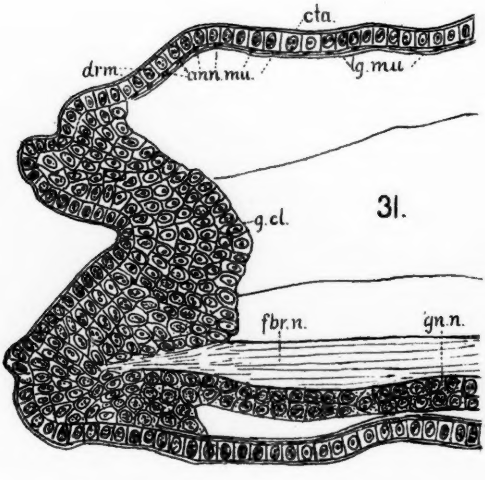

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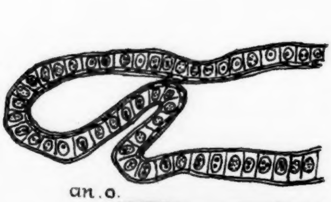

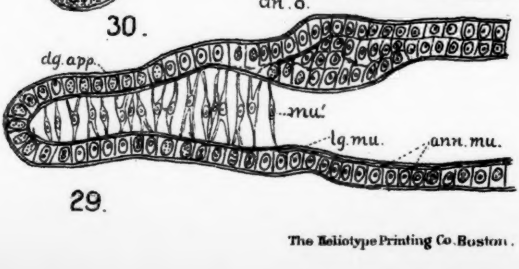

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VII.

CONTRIBUTIONS FROM THE ZOÖLOGICAL LABORATORY OF THE MUSEUM OF COMPARATIVE ZOÖLOGY AT HARVARD COLLEGE.

No. VII. — DESCRIPTIONS OF NEW SPECIES OF *CAMBARUS;* TO WHICH IS ADDED A SYNONYMICAL LIST OF THE KNOWN SPECIES OF *CAMBARUS* AND *ASTACUS.*

By Walter Faxon.

Communicated November 12th, 1884.

Sixteen years have elapsed since the North American Crayfishes were revised by Dr. Hagen.* In the mean while a large amount of new material has accumulated in the Museum of Comparative Zoölogy. On examination, this material revealed so many new forms, and shed so much light on the variability and geographical distribution of these animals, that it seemed desirable to subject the group anew to a critical revision. With this in view I have examined all the collections accessible, including those belonging to the Museum of Comparative Zoölogy, the Boston Society of Natural History, the Peabody Academy of Science at Salem, Mass., the Academy of Natural Sciences of Philadelphia, the United States National Museum at Washington, D. C., Yale College, New Haven, Conn., Bowdoin College, Brunswick, Me., and Butler University, Irvington, Ind., together with the private collections of Mr. P. R. Uhler of Baltimore, Md., Prof. O. P. Hay of Irvington, Ind., Prof. L. A. Lee of Brunswick, Me., Prof. A. S. Packard of Providence, R. I., Prof. D. S. Jordan of Washington, D. C., Mr. R. S. Tarr of Gloucester, Mass., Dr. C. Hart Merriam of Locust Grove, N. Y., and Prof. B. F. Koons of Mansfield, Conn. Only through the kind offices of the curators of these collections was a thorough revision of this difficult group possible. I have now ready for the press the first part of a revision of the *Astacina*, embracing

* Ill. Cat. Mus. Comp. Zoöl., No. III. This monograph was finished in 1868, although not published until 1870.

all the Crayfishes found in the Northern hemisphere, viz. the family *Potamobiidæ* of Huxley. Owing to unavoidable delay in the publication of the full Revision in the Memoirs of the Museum of Comparative Zoölogy, illustrated by quarto lithographic plates, it is thought advisable to publish the following descriptions of the new species. All of them will be figured in the final Memoir.

Genus CAMBARUS.

§ 1. *Third and fourth pairs of legs of male furnished with hooks on the third segment. First abdominal appendages of the male with outer part truncate at the tip and furnished with one to three small recurved teeth, inner part ending in an acute spine which is generally directed outwards.*

a. *Rostrum with ante-apical lateral spines.*

1. C. Hayi, sp. nov.

Male, form I. Rostrum broad, triangular, excavated, sparsely pubescent above, acumen short, lateral spines moderate. Carapace punctate above, granulated on the sides, the granules ciliate. Lateral spines slightly developed in fully-grown individuals, more prominent in the young. Areola narrow. Abdomen broad, shorter than the cephalo-thorax. Pleural angles rounded. Proximal segment of telson with two spines on each side of the distal border. Hind margin of telson slightly concave. Anterior process of epistoma broadly triangular. Antennæ shorter than the body. Antennal scale a little shorter than the peduncle, equal to the rostrum, broad, broadest at the middle. Chelipeds slender, chela long, inner and outer margins parallel, squamoso-tuberculate, tubercles ciliate, those along the inner margin of the hand blunt spiniform. Fingers longer than the hand. Opposed margins of fingers ciliate, with one or two small spinous teeth. Carpus long triangular, smooth without, tuberculate and spinous within. Meros with scattered puncta without, tuberculate on the upper margin, one or two spines at the anterior end of upper margin, two rows of spines beneath. Third and fourth pairs of legs hooked on third segments. Anterior abdominal legs of moderate length, deeply excavated on the outer side near the tip. A beard-like tuft of cilia from the protuberance behind the excavation. Tip bears three flattened horny teeth. Inner part ciliate, with a long spine directed outwards and forwards.

The second form of the male has shorter chelipeds, smaller hooks

on the second and third pairs of legs, the terminal teeth of the first pair of abdominal legs smaller and not corneous.

In the female the chelipeds are short, the chelæ broad. Sternum bituberculate between the fourth pair of legs. Annulus ventralis umbilicoid, with a tubercle in the median depression.

Length, 100 mm. Rostrum, 15 mm.; acumen, 3 mm. Length of carapace, 51 mm. From cervical groove to posterior margin of carapace, 18.5 mm. Abdomen, 50 mm. Width of areola, 1.5 mm. Chelipeds, 92 mm. Chela, 43 mm.

Known localities. Mississippi: Macon, Artesia.

Closely related to *Cambarus Blandingii*, but easily distinguished by the first pair of abdominal legs of the male, which are characteristic even in very small specimens. Over a dozen specimens of this species (including males of the first form, males of the second form with first pair of abdominal appendages articulated near the base, and unarticulated, and females) were collected by Prof. O. P. Hay in Eastern Mississippi. One lot has a particular locality specified, Macon. Macon is situated on the Noxubee, an affluent of the Tombigbee River. Another lot was collected at Artesia, a town about twenty miles north of Macon.

2. C. PUBESCENS, sp. nov.

Male, form II. Rostrum long, triangular, sides sub-parallel at the base, then converging towards the lateral spines, which are evident; slightly depressed above at the base, subplane, with raised margins; ciliated especially on the acumen; acumen long, pointed. Postorbital ridges with anterior spines. Carapace cylindrical, fore border angulated behind the antennæ, punctate above, slightly granulated on the sides, with one lateral spine on each side. Cervical groove ciliated. Cardiac region short (much less than one third as long as the anterior part of the carapace). Areola broad. Sternum covered with a dense growth of coarse setæ. Abdomen longer than the cephalo-thorax. Proximal segment of telson armed on each side with four spines. Anterior process of epistoma broad triangular with ciliated margin. Basal segment of antennule with a sharp spine below near the inner margin of the middle of its length. Antennæ shorter than the body. Second and third segments with acute external spine; scale a little longer than peduncle of antennæ and rostrum, moderately broad, broadest below the middle. Third maxillipeds hairy within and below. Chela moderately broad, covered with inconspicuous ciliate squamous tubercles, internal margin nearly straight.

Fingers as long as the hand, densely ciliated. Carpus tuberculate, a prominent spine within, and one near each point of articulation with the chela. Meros smooth outside and inside, tuberculate and spinous above, biserially spinous and ciliate beneath. Third and fourth pairs of legs toothed on the third segment. Fifth pair of legs with a hook on the basal segment. Anterior abdominal appendages of moderate length, articulated at the base, internal part with an articulated spine obliquely placed, external part terminating in a rounded head with two short, blunt teeth.

Female. Differs from the male in its shorter and smaller claws. The sternum is densely ciliated as in the male. The annulus ventralis conical with sigmoid longitudinal fissure; movable.

Length, 54 mm. Carapace, 26 mm. Abdomen, 29 mm. Distance from tip of rostrum to cervical groove, 19 mm; from cervical groove to posterior border of carapace, 7 mm. Width of areola, 3 mm. Length of chela, 15.5 mm.; breadth, 4 mm. (In the female, which is 59 mm. long, the chela is 12 mm. long by 4 mm. wide.)

Two specimens, one male of the second form and one female, in the U. S. National Museum (No. 3181), collected by A. Graves in McBean Creek, a tributary of the Savannah River a little south of Augusta, Georgia, are the types of this species. There are two young female specimens from the same region, Richmond Co., in the Museum of Comparative Zoölogy.

Differs from *C. Lecontei* and *C. angustatus* by its broader areola, subplane rostrum, and the pubescence of rostrum and cervical groove. The male appendages also differ, as shown in the description.

b. *Rostrum without ante-apical lateral spines (at least in full-grown specimens).*

3. C. Alleni, sp. nov.

Male, form I. Rostrum broad, triangular, somewhat deflexed, smooth, excavated above, margins raised into sharp crests and gradually converging to near the tip, where they suddenly approximate each other to form the short, sharp acumen; no lateral spines. Post-orbital ridges without spines. Carapace cylindrical, somewhat compressed laterally, fore border angulated behind the antennæ, punctate above, granulated on the sides. Cervical groove deeply sulcated, without lateral spines. Cardiac region more than one third as long as the distance from the tip of rostrum to hind border of carapace. Areola narrow. Abdomen broad, longer than cephalo-thorax. Angles of pleura rounded. Three or four spines on each side of posterior border

of basal segment of the telson. Terminal segment of telson shorter than basal part, one third broader than long, hind margin concave. Anterior process of epistoma subquadrangular. Basal segment of antennules with a sharp spine below near the inner margin, half-way towards the end of the segment. Antennæ shorter than the body, second and third segments with an external sharp tooth. Antennal scale equal to peduncle, slightly surpassing the rostrum, broad, broadest at the middle, rounded at apex, terminating in a short spine, external margin inflated. Third maxillipeds hairy within and below. Chelipeds slender, chela long, subcylindrical, squamoso-tuberculate, tubercles ciliate anteriorly, internal border straight, serrate. Fingers as long as the hand, with alternate longitudinal ribs and lines of ciliate impressed dots. Opposed margins of fingers straight, unidentate. Carpus squamoso-tuberculate within, obsoletely so without, with one prominent spine on inner border. Meros punctate outside, ciliato-tuberculate within and on upper margin, which has two ante-apical spines obliquely placed; two rows of spines beneath. Third and fourth pairs of legs hooked on third segments, hooks of fourth pair bituberculate. Fifth pair of legs with a flattened laminate tubercle on basal joint. Anterior abdominal appendages of moderate length, bifid at apex, outer part forming a broad flattened plate whose anterior margin is furnished with hairs and one strong seta, the posterior margin of the plate produced anteriorly into a blunt tooth-like process. Inner part bearded within, and produced into a long erect spine, which much exceeds in length the outer part of the appendage.

Length, 62 mm. Rostrum, 6 mm. Carapace, 30 mm. From tip of rostrum to cervical groove, 19.5 mm. From cervical groove to posterior border of carapace, 10.5 mm. Abdomen, 32 mm. Width of areola, 7 mm. Antennæ, 47 mm. Chelipeds, 49 mm. Chela, 23 mm. Width of chela, 6 mm.

St. John's River, Hawkinsville, Orange Co., Fla.: J. A. Allen.

A well-marked species with toothless excavated rostrum (younger specimens probably have marginal rostral teeth), narrow areola, long, subcylindrical chelipeds covered with ciliated squamous tubercles. The first abdominal legs are not jointed, the hooks on the third and fourth pairs of thoracic legs are large and well-finished, so that I consider the single specimen examined to be the first form.

In the collection of the Academy of Natural Sciences of Philadelphia there is a specimen from Hernando Co., Fla., Jos. W. Wilcox, which is probably the second form of the male of this species. The sexual appendages are not articulated at the base. The hooks on the

third and fourth pairs of legs are small tooth-like processes merely. Besides the differences in these hooks and in the sexual appendages the following may be pointed out: the rostrum has small lateral teeth near the tip, the post-orbital ridges have a sharp spine at their anterior end, the basal segment of the fifth pair of legs is armed with a sharp hooked tooth in place of a flattened tubercle, and the hind segment of the telson is longer in proportion to its width.

§ 2. *Third pair of legs of male hooked. First pair of abdominal appendages of male as in* § 1.

4. C. SIMULANS, sp. nov.

Male, form I. Rostrum broad, deeply excavated; margins raised into sharp crests which overhang the base of the sides of the rostrum, converging, sinuated before the tip to form the short acumen; no lateral spines; the acumen is barely margined. Post-orbital ridges subacute in front, divergent and ending in slight callosities behind. Carapace ovate, narrowing in front, gastric area smooth, cardiac area lightly punctate, sides granulate; anterior border notched behind the antennæ; cervical groove sinuate, split on the sides, with a minute terminal branchiostegian spine; no lateral spine; areola more than one half as long as the distance from the point of the rostrum to cervical groove, narrow, carinate, expanding into an anterior and a posterior triangular field; two longitudinal dotted lines run along the areola from the anterior triangle to the posterior triangle, which is irregularly and sparsely dotted. Abdomen broad, shorter than carapace, punctate, posterior margins of pleura obliquely convex; hind margin of anterior segment of telson bi- to multi-denticulate on each side, posterior segment short, hind border almost straight; median rib of inner plate of swimmeret ends inside of the margin. Basal segment of antennule with a spine below. Antennæ shorter than body, second and third segments furnished with minute blunt spinules, scale a trifle longer than the rostrum, very broad, broadest in the middle, truncate at apex, external terminal spine minute. Anterior process of the epistoma triangular, antero-lateral borders convex, rimmed, anterior angle truncate or notched in old specimens, with a projecting median spine. Third maxillipeds densely hairy within and beneath. Chela long, slender, squamoso-tuberculate, internal margin long, straight, strongly dentate; fingers long, punctate, external border of movable finger tuberculate, inner border of both fingers toothed, a prominent tubercle near the base of external finger opposite a more or less clearly marked incision

in the base of the thumb. Carpus triangular, obliquely truncate, inner margin armed with a stout spine and some low, scattered tubercles, lower side with two or three teeth and numerous small tubercles. Superior margin of meros with short spines, which are sometimes obsolescent except the distal ones; below, the biserial spines are well developed. Sternum hairy. Third pair of legs hooked. First pair of abdominal appendages strong, straight, internal part with a very small, straight apical spine, which does not reach the end of the external part; external part with two horny terminal teeth, one of which is flat and disc-shaped, the other slender and somewhat curved.

Length, 97 mm. Breadth, 27 mm. Length of carapace, 51 mm. Length of areola, 18 mm. Width of areola, 1.3 mm. Length of rostrum, 11.5 mm. Length of chela, 50.5 mm.

Male, form II. Chelipeds smaller, hooks on the third pair of legs smaller, first abdominal appendages without horny teeth at apex.

Female. Chelæ smaller and shorter-fingered than in the male; annulus ventralis bituberculate in front, each tubercle denticulate.

Known localities. Texas: Dallas; east of Canadian River (Coll. U. S. Nat. Mus.). Kansas: Fort Hays.

This species is remarkable in having the general form of body and claw of the *C. Blandingii* group of species, while the fact that only the third pair of legs are hooked places it in the *C. advena* group. The male appendages and the female annulus are very near to those of *C. gracilis*. In the shape of the body, areola, antennal scale, and claw, it resembles *C. Blandingii, var. acuta*, but the rostrum is deeply excavated, and toothless even in small specimens. The full cephalo-thorax and large abdomen seem to indicate that it is not a pre-eminently burrowing species, like its allies, *C. gracilis*, *C. advena*, &c.

There are specimens in the United States National Museum collected by the United States Exploring Expedition West of the Hundredth Meridian in pools east of the Canadian River. This locality, I presume, is within the limits of the State of Texas.

§ 3. ***Third pair of legs of male hooked. First pair of abdominal appendages of male thick, terminating in two short, recurved teeth.***

a. *Rostrum devoid of lateral teeth.*

5. C. ACUMINATUS, sp. nov.

Rostrum long, tapering, ending in a long, sharp acumen, without lateral spines; upper surface smooth, somewhat hollowed out, margins punctate, ciliate, raised into low sharp crests. Post-orbital ridges with

sharp anterior spines. Carapace smooth, punctate, granulated on the sides, cervical groove sulcate, sinuate; a sharp lateral and branchiostegian spine; sub-orbital angle rounded; an irregular indentation on the side of the carapace, below the lateral spine, on the hepatic region and anterior part of the branchial region; areola broad, smooth, punctate, less than one half as long as the distance from the tip of the rostrum to the cervical groove. Telson bispinose on each side. Epistoma triangular, angles rounded. Second and third segment of the antennæ with a strong sharp spine; scale of moderate length, rather broad, inner margin rounded, outer margin thick, turned outwards at the tip. Third maxillipeds hairy within. Chela moderate, punctate, serrato-tuberculate on internal border, fingers setose on their inner margins, external border of outer finger submarginate. Carpus armed with a strong internal spine and smaller inferior median and external spines. Meros with well-developed biserial spines below and two obliquely placed near the distal end of the superior border. In some specimens one of the superior pair is obsolete. Third pair of legs hooked. First pair of abdominal appendages as in *C. Bartonii.*

Length, 48 mm. Carapace, 23 mm. Rostrum, 6 mm. Areola, 7 mm. Breadth of areola, 2 mm.

Saluda River, west of Greenville, S. C. Collected by Prof. D. S. Jordan. Three specimens, one male of the second form, two females. For the opportunity to examine these I am indebted to Prof. O. P. Hay of Butler University, Irvington, Ind. Differs from the other species of the *C. Bartonii* group by its long, gradually tapering rostrum, short metacarapace, strongly developed spines of carapace, antennæ, and meros. The acumen of the rostrum is scarcely upturned at the tip.

Specimens from North Carolina, Old Fort, McDowell Co., and French Broad River, (in Mus. Comp. Zoöl. and Acad. Nat. Sci. Phila.), differ from the above in having the rostrum flatter and less attenuated at the tip, a shorter antennal scale, sub-orbital angle produced into a sharp spine. These may prove to be a distinct species from the Saluda River specimens. They approach *C. robustus*, but may be distinguished from that species by the longer-pointed rostrum, shorter metacarapace, better-developed spines, etc.

6. C. DUBIUS, sp. nov.

Rostrum short, broad, sides sub-parallel from the base to near the tip, when they suddenly converge to form the short, broadly triangular acumen; the rostrum is angulated but not toothed at the base of the

acumen; upper surface of rostrum concave, sides thickened, punctate-lined. Post-orbital ridges without spines, slightly swollen at the posterior end. Carapace longer than the abdomen, oval, punctate, granulated on sides, posterior dorsal margin depressed, cervical groove hardly sinuate, crossing the median line of the back half-way between the base of the rostrum and the posterior margin of the carapace; lateral and branchiostegian spines obsolete; sub-orbital angle little developed, obtuse; areola narrow, with two irregular longitudinal rows of dots. Epistoma subquadrangular. Abdomen small, short; anterior segment of telson bispinose on each side, posterior segment rounded behind. Antennæ shorter than the body, second and third segments without spines, scale small. External maxillipeds hairy within. Chela punctate, inner margin of hand serrato-tuberculate, outer margin thickened, serrate; fingers somewhat down-curved, slightly gaping, toothed on their opposed margins. Carpus with a strong tooth on the inner side, teeth of the lower side obsolescent. Superior border of meros serrate, lower side armed with two rows of spines. Third pair of legs hooked. First pair of abdominal legs of the first form of the male short, thick, twisted, internal part cylindrical, recurved, with pointed apex; external part broader, plane within, apex recurved, compressed, external margin corneous, striated.

Length, 62 mm. Length of carapace, 33.5 mm. Length of abdomen, 28.5 mm. Length of rostrum, 5 mm. Metacarapace, 15 mm. Width of areola, 1.5 mm.

Known localities. West Virginia: Cranberry Summit, Preston Co. Virginia: Pennington's Gap, Lee Co. Tennessee: Cumberland Gap.

This species has the general appearance of *C. Diogenes*, but the rostrum is short, as in *C. Bartonii*, and the areola is not obliterated in the middle by the apposition of the branchio-cardiac lines. The few (four) specimens which I have seen come from the Appalachian Mountain region of Virginia and West Virginia. According to Mr. Uhler, it makes mud chimneys like *C. Diogenes*, which it seems to represent in the mountain regions, *C. Diogenes* belonging to the lowlands.

7. C. ARGILLICOLA, sp. nov.

Rostrum short, broad, down-curved, excavated, with a deep foveola at base; acumen short, broadly triangular, acute, no lateral spines. Post-orbital ridges without anterior spines, swollen behind. Cephalothorax laterally compressed, carapace punctate, anterior border not angulated, cervical groove sinuate, no lateral or branchiostegian spine.

Areola linear in the middle, with an anterior and posterior triangular space, the latter the larger. Abdomen broad, but narrow at the base, longer than the cephalo-thorax. Telson uni- or bi-spinose on each side. Epistoma rounded in front. Antennal scale small, rounded within. Third maxillipeds heavily bearded within, lightly so beneath. Chela large, hand swollen, denticulate on inner border, irregularly punctate, fingers flattened laterally, punctate and costate; the movable finger has a single row of tubercles on external border and a very prominent rib on its upper face, its internal, cutting edge is toothed and excised at the base. The outer finger is sharply marginate on its external border, inner border toothed and heavily bearded at the base. Carpus armed with a sharp spine and a few minute tubercles within; beneath them is a sharp median anterior spine, and a minute spiniform tubercle between this and the spine of the internal border. Meros furnished with one or two small sub-apical teeth on the superior border, and two rows of teeth below. Second pair of legs ciliate near the end. Third pair of legs of male hooked. First abdominal appendages of male and annulus of female as in *C. Diogenes*.

Length, 76 mm.

Known localities. Dominion of Canada: Toronto, Prov. Ontario. Michigan: Detroit, East Saginaw (Coll. Peabody Mus. Yale Coll.). Indiana: New Albany. Louisiana: New Orleans (Coll. U. S. Nat. Mus.). North Carolina: Kinston.

Closely related to *C. Diogenes*, but at once distinguished by the sharply compressed fingers bearded at the base, excised thumb with a single row of tubercles on external margin, non-angulated anterior border of carapace, etc. The types of this species were dug out of burrows in solid blue clay in Detroit, Mich., by Mr. H. G. Hubbard, in August, 1873. The burrows were three to five feet deep. At the bottom of each burrow was a pocket in a layer of loose gravel and clay, holding water. Just above the water-line an enlargement in the burrow formed a shelf on which the animal rested.

Specimens from Kinston, N. C., and New Orleans, La., which I have referred to this species, are not adult, and cannot be determined with absolute certainty.

8. C. Uhleri, sp. nov.

Male, form I. Rostrum of moderate length, sides nearly parallel to base of acumen, which is broadly triangular, acute; no lateral spines; upper surface of rostrum plane, punctate, lightly foveolate at base, margins raised into a low, sharp crest, punctate-lineate; there is

a faint trace of a median longitudinal carina. Post-orbital ridges without anterior spines, swollen posteriorly. Carapace oval, punctate, granular on sides. Antero-lateral border not angulate or notched. No lateral or branchiostegian spines. Cervical groove sub-sinuate. Areola none. Abdomen longer than cephalo-thorax. Anterior segment of telson bispinose on each side, posterior segment round behind. Epistoma triangular. Antennæ short, with very small spines on the second and third segments, scale short, broad, inner margin rounded. Third maxillipeds hairy within and beneath. Chela moderate, hand inflated, punctate, ciliate, inner margin ornamented with a row of sharp dentiform tubercles, outside of which is a row of smaller tubercles. Fingers compressed, punctate and costate, movable finger with a single row of tubercles on the outer edge, a prominent rib running along the middle of the upper surface, inner margin excised at base and furnished with tuberculiform teeth. External finger toothed within, hairy at base, outer border marginate. Carpus armed with a strong tooth and a few small scattered tubercles on the inner side, a stout median anterior spine beneath, and two or three smaller ones between the median and internal spine. Superior border of meros serrate, inferior surface with two longitudinal rows of spines. Second pair of legs densely ciliate on the inner side near the tip. Third pair of legs hooked. First pair of abdominal appendages of male and annulus of female as in *C. Diogenes.*

Length, 65 mm. Carapace, 30.5 mm. Rostrum, 6.5 mm.

Known localities. Maryland: Carolina Co. (Coll. P. R. Uhler); Dorchester Co.; Talbot Co. (Coll. P. R. Uhler); St. Mary's Co. (Coll. P. R. Uhler); Wicomico Co. (Coll. P. R. Uhler); Somerset Co.; Worcester Co.

This species was discovered by Mr. P. R. Uhler, of Baltimore, in the counties of Maryland enumerated above, on the Chesapeake and Atlantic coasts of Maryland. It is found in salt marshes, covered twice daily by the tides, and also in brackish and fresh-water ditches in company with *C. Blandingii.* In Dorchester County it is found far back in the lowlands in the neighborhood of Vienna.

C. Uhleri is easily distinguished from *C. Diogenes* and *C. argillicola* by its plane rostrum, shape of the hand, etc.

b. *Rostrum with small lateral teeth.*

9. C. Girardianus, sp. nov.

Male, form II. Rostrum broad, excavated, margins with a line of puncta, slightly convergent; acumen long, ending in a brown corneous

upturned tip; a pair of minute, brown horny teeth at base of the acumen. Post-orbital ridges depressed, with sharp anterior spines. Cephalo-thorax as long as the abdomen. Carapace flattened above, densely and finely punctate, slightly granulated and finely ciliated on the branchial and hepatic regions. Cervical groove sulcate, sinuate, with minute lateral spine and terminating with a small branchiostegian spine; external angle of the orbit very prominent, ending in a spinule. Areola long and wide, plane, punctate, in length more than one half the distance between the tip of rostrum and posterior margin of the carapace; sides nearly parallel to within a short distance of the posterior margin, where they diverge. Telson bispinous on each side. Anterior process of epistoma broad. Antennæ longer than the body, scale moderately broad, ending in long, acute apical spine. Third pair of maxillipeds hairy within. Chelipeds moderate; chela large, densely punctate, inner margin short, lightly serrate; fingers long, with parallel rows of puncta, toothed within, outer one bearded within at base. Carpus broad, obliquely truncated, punctate above, with a strong median spine on the inner side and a small double one at the base; below the carpus is armed with a spine on the anterior border. Meros smooth, with a single ante-apical spine on the upper edge and the usual biserial ones beneath; of the latter, only two or three at the proximal end are developed. Thoracic sterna naked. Third pair of legs hooked on the third segment. Fourth pair of legs with a small ovate basal tubercle. First pair of abdominal appendages articulated near the proximal end, stout, short, swollen in the middle. External part with the compressed apex in the form of a strong, obtuse, recurved tooth, double within; internal part recurved, cylindrical, short, acute.

Female. Annulus ventralis transverse, with a sigmoid sulcus.

Measurements of an individual: —

Length of body	60	mm.
" " cephalo-thorax	31	"
" " abdomen	29	"
From tip of rostrum to cervical groove	20	"
From cervical groove to hind margin of carapace	11	"
Width of areola	3.5	"
Length of rostrum	7.5	"
" " acumen of rostrum	2.5	"
" " chela	20	"
" " inner margin of hand	7	"
" " fingers	13	"
" " antennæ	58	"

Cyprus Creek, Lauderdale Co., Ala.

This species is near *C. extraneus,* but differs in its longer and narrower areola, in the short hand and long fingers, the single superior ante-apical spine on the meros, naked thoracic sterna (in *C. extraneus* they are setiferous), the greater smoothness of the body altogether, and the fineness of the punctation of the carapace; the sub-orbital angle is very much more projecting than in *C. extraneus.*

This species was discovered by Mr. C. L. Herrick in Cyprus Creek, Lauderdale Co., Ala., when collecting under the auspices of the U. S. National Museum, in October, 1882. The specimens obtained were two males, form II., and three females.

10. C. Jordani, sp. nov.

Male, form II. Rostrum broad, subplane, sides nearly parallel, acumen long, with minute lateral teeth at base. Post-orbital ridges provided with sharp anterior spines. Carapace punctate (sparsely so on the gastric region), slightly granulated on the sides. A single acute spine on each side of the carapace behind the cervical groove, and a branchiostegian spine on the anterior border. Sub-orbital angle prominent. Areola long, narrow, widening gradually anteriorly, suddenly posteriorly, smooth, with but few puncta irregularly disposed in its field. Abdomen longer than the cephalo-thorax; proximal segment of the telson bispinous, distal segment rounded posteriorly. Epistoma triangular. Antennæ equal in length to the body minus the telson, scale broad, greatest width toward the distal end, which is subtruncate and furnished with a sharp external spine. Third pair of maxillipeds hairy within. Chela punctate, ciliate; inner margin of hand short, serrate ; fingers long, costate, outer border of movable one serrato-tuberculate. Carpus with a strong, acute, median spine, and a small basal spine on inner border; a small spine at each articulation with the chela. Meros smooth on the external surface, two ante-apical spines obliquely placed on the upper edge. First pair of abdominal appendages short, thick, articulated near the base, terminating in two blunt, recurved teeth.

Length of body	47	mm.
" " carapace	23	"
" " abdomen	24	"
" " rostrum	6	"
" " acumen of rostrum	2	"
Length from point of rostrum to cervical groove	15	"
" " cervical groove to hind margin of carapace . .	8	"
Width of areola.	1.3	"
Length of antennæ	44	"

Of this species I have seen but one specimen, a male of the second form, collected by Prof. D. S. Jordan in the Etowah River near Rome, Georgia, communicated by Mr. P. R. Uhler of Baltimore. It has a toothed rostrum and first abdominal appendages like *C. Bartonii.* It is distinguished from the other allied species by its flat rostrum and narrow areola.

11. C. CORNUTUS, sp. nov.

Male, form I. Rostrum long, narrow, excavated above; margins divergent at the base, thickened, concave, costate; acumen long, with upturned horny tip; lateral teeth at base of acumen upright, stout, blunt, horny. Post-orbital ridges sulcate on the outer side, with well-developed horny-tipped anterior spines. Carapace flat, smooth, and punctate above, granulated on the sides; a depression on each side just outside the orbital ridges; no sub-orbital angle nor spine; cervical groove sulcated, sinuate, with a strong, sharp lateral spine; no branchiostegal spine; areola long, of moderate width, plane, punctate, widening at the posterior end of the carapace. The length of the areola is equal to the distance from the cervical groove to the base of the rostrum. Abdomen broad, as long as the cephalo-thorax without the acumen of the rostrum, pleura triangular, with sharp lateral angles. Terminal segment of telson broader than long, posterior border rounded; anterior segment of telson bispinous on each side. Anterior process of epistoma very broad, short, triangular; apex not truncated nor notched. Thoracic sterna ciliated. Basal segment of antennule with a spine on lower side on the distal half of the segment. Antennæ longer than the body, flagellum very large, composed of annulations flattened in the vertical direction, conspicuously bearded along the inner margin. Antennal scale oblique to the horizontal plane of the body, a little longer than the rostrum, inner margin straight and parallel with the outer margin, sub-truncate at the tip, apical spine strong, long and acute; second segment of antenna with a large external spine at base of the scale; another small but well-formed external spine on the following segment, below. Chelipeds large. Chela of moderate size; hand smooth, punctate, internal margin serrate; fingers of moderate length, curved slightly downwards, ribbed and punctate above, tips incurved, horny; external finger serrate on outer margin, impressed above and below at base; inner borders of fingers tuberculate and ciliated especially at their bases. Carpus smooth, lightly punctate above, with a strong median internal spine and a small basal internal spine; a sharp, prominent median anterior spine beneath. Meros smooth, a

single acute ante-apical spine on the superior margin, only one or two distal spines in the outer row of biserial spines beneath. Third joint of third pair of legs hooked. Fourth pair of legs with a conical tubercle on the first segment. First pair of abdominal appendages short, stout, twisted, distal half bent in towards the median line of the body; internal part truncate at apex, with a small spine directed backward and outward; external part longer, ending in a short, recurved, blunt, laterally compressed, horny tooth.

Measurements : —

Length of body	81	mm.
" " cephalo-thorax	43.5	"
" " abdomen	37.5	"
Length from tip of rostrum to cervical groove	27	"
From cervical groove to posterior border of carapace	16	"
Length of rostrum	11	"
" " acumen of rostrum	5	"
Width of base of acumen of rostrum	3	"
" " areola	3	"
Length of antennæ	91	"
" " chela	36	"
Width of chela	15	"
Length of movable finger	22	"

One specimen, collected by Mr. F. W. Putnam in Green River near the Mammoth Cave, Kentucky, November 3, 1874.

This species is very distinct from every other known Crayfish. In its general appearance it approaches those species included in the group typified by *C. Bartonii*. The rostrum, however, is more after the fashion of *C. rusticus*, but the lateral spines are much larger and stand erect. The impressed external finger recalls *C. robustus*. The sexual appendages are formed nearly as in *C. Bartonii*. The development of the antennæ is extraordinary.

§ 4. *Third pair of legs of male hooked. First pair of abdominal appendages of male terminating in two elongated, straight tips.*

a. *Rostrum without lateral teeth.*

12. C. MEDIUS, sp. nov.

Male, form I. Rostrum of moderate length, excavated, slightly carinated at the tip; margins thickened, converging, sinuated near the tip to form the short triangular acumen; no lateral spines. Post-orbital ridges depressed, sulcated on external face, subacute anteriorly. Cara-

pace subcylindrical, somewhat flattened above, punctate, granulated on the sides; cervical groove sinuate, no lateral nor branchiostegian spine; sub-orbital angle rounded; areola long (much more than one half as long as the distance from the cervical groove to the tip of the rostrum), of moderate width, punctate, widening posteriorly. Abdomen as long as the cephalo-thorax; telson rounded behind, basal segment bispinous on each side of the posterior border. Basal segment of antennule with an interior median spine. Second and third segments of antennæ not spiniferous (flagellum of antennæ broken off in the specimen examined, probably much shorter than the body). Antennal scale short, of moderate width, terminating in a short, acute spine. Anterior process of epistoma triangular, apex pointed, sides convex. Third maxillipeds bearded within. Chelipeds of moderate length, stout; chela broad, inflated, coarsely punctate above and below, external margin rounded; internal margin of hand with a double row of obsolescent tubercles; fingers stout, gaping at base, costate, heavily dotted-lined, internal margins furnished with rounded tubercles. Carpus sparsely punctate, armed with a moderate median and a smaller basal internal spine; below, there are no spines developed. Meros furnished with two nearly obsolete obliquely-placed tubercles near the distal extremity of superior border, and with a double row of tubercles below. Second pair of legs provided with long cilia towards their distal extremity. Third segment of third pair of legs hooked. First pair of abdominal legs long (reaching to base of chelipeds), deeply bifid, rami slender, straight, the outer one a little recurved at the tip, aciculate, the inner one slightly dilated near the tip, blunt pointed; a projecting angle or shoulder at base of rami on anterior margin.

Female. Hand small, fingers not gaping, ciliated within; sternum between fourth pair of legs plane; annulus ventralis bilaterally symmetrical, anterior border bituberculate, posterior border unituberculate, transverse fossa deep, recurved at each end.

Measurements of male, form I.: — Length of body, 49 mm. Length of carapace, 25 mm. Length of rostrum, 6 mm. Length from end of rostrum to cervical groove, 15.5 mm. Length from cervical groove to hind border of carapace, 9.5 mm. Width of areola, 2 mm. Length of abdomen, 25 mm. Length of chela, 23.5 mm. Length of internal margin of hand, 9.5 mm. Breadth of chela, 11.5 mm. Length of movable finger, 14 mm.

Two specimens, first form of male and female, in the Museum of Comparative Zoölogy, from Irondale, Mo.

This species has the general form of body, rostrum, and chelæ of

the *C. Bartonii* group, together with the male abdominal appendages of the *C. affinis* group. These appendages have a projecting shoulder at the base of the rami, on the anterior edge, as in *C. rusticus*, *C. Putnami*, etc. *C. immunis* and *C. Mississippiensis*, belonging to the *C. affinis* group, also have the rostrum devoid of lateral spines, but in general habit of body they do not resemble *C. Bartonii* and its allies, as is the case with the present species.

13. C. Mississippiensis, sp. nov.

Male, form I. Rostrum broad, twice as long as broad, sub-excavated above, smooth, foveolate at base, margins raised, converging anteriorly, sinuate at apex; acumen short, triangular, acute, no lateral teeth. Post-orbital ridges sulcate on outer side, with short, blunt anterior spines. Carapace densely punctate, sides lightly granulate, front lateral border not angulated. Cervical groove sinuate, with small lateral and branchiostegian spines. Areola linear anteriorly to the middle, with a small anterior and a larger posterior, triangular field. Length of areola equal to half the distance from tip of rostrum to cervical groove. Abdomen as long as the carapace. Terminal segment of the telson shorter than the basal segment, hind border slightly concave at the centre; basal segment bispinose on each side. Anterior angle of epistoma notched. Sternum between the legs densely ciliated. Antennal scale very broad, apical spine short. Third maxillipeds hairy without and beneath. Chelæ large, punctate, smooth below, margined without; inner margin of hand short, furnished with dentiform tubercles irregularly disposed in a double series; a little distance from these is another line of smaller ciliated tubercles on the upper surface of the hand on a line with the middle of the base of the movable finger. Fingers long, gaping at base, each with a punctate impressed line parallel with inner margin, and furnished with rounded tubercles on inner margin. Movable finger tuberculate on outer margin. Outer finger bearded below at base. Carpus broad, obliquely truncate on the external side, punctate and tuberculate above, a strong median internal spine, two small spines near on the base and one at the anterior end near the articulation; multispinous beneath, the two anterior spines the largest. Meros smooth, two ante-apical spines obliquely placed on upper margin, lower face with blunt biserial spines. Second pair of legs with long setæ near the end on inner side, not tufted as in *C. immunis*. Third pair of legs hooked. First pair of abdominal appendages long, deeply bifid, rami recurved at tip, parallel, internal ramus sub-cylindrical, dilated and grooved at tip,

external ramus a little longer than the internal, laterally flattened, ending in a slender, sharp point.

Male, form II. Rostrum with small lateral teeth; hand smaller, with smaller tubercles; hooks on third legs smaller; third pair of abdominal appendages stouter, cleft for only a short distance from the tip, tips blunt, no articulation at the base in the one specimen examined.

Female. Rostrum as in the second form of the male. Hand shorter and broader, annulus ventralis with a very deeply excavated fossa.

Measurements of male, form I.: — Length, 73 mm. Length of rostrum, 9 mm. Breadth of rostrum at base, 5 mm. Length of areola, 11 mm. From tip of rostrum to cervical groove, 25 mm. Length of chela, 35 mm. Breadth of chela, 14 mm. Length of inner finger, 24 mm. Length of internal margin of hand, 11 mm.

Five specimens, one male, form I., one male, form II., and three females, were collected by Prof. O. P. Hay in Eastern Mississippi. Two of them are labelled "Macon, Miss."

Differs from *C. immunis* in its linear areola, flatter rostrum, differently shaped chela, and male appendages, the rami of which are longer and less strongly recurved. *C. Palmeri* differs from it in its quadrangular rostrum, which has a longer acumen and more prominent lateral spines, narrower and long-spined antennal scale, longer areola; the rami of the male appendages (form II.) are a little longer and more widely separated. *C. Alabamensis* differs by its wide areola, toothed and carinated rostrum, etc.; *C. compressus*, by its laterally compressed carapace, wide areola, narrow carinated rostrum, etc.

b. *Rostrum with lateral teeth.*

14. C. Palmeri, sp. nov.

Male, form II. Rostrum broad, sub-excavated, margins nearly parallel from base to lateral spines, which are small and sharp; acumen long. Post-orbital ridge with sharp anterior spine. Carapace smooth and punctate above, granulate on sides, lateral spine of moderate size, anterior lateral border notched just below the sub-orbital angle, which is not prominent. Areola linear for a short distance anterior to the centre, with a small anterior and a larger posterior triangular field. The length of the areola is one half the distance from cervical groove to tip of rostrum. Abdomen as long as the cephalothorax. Proximal segment of telson bispinose on each side. Antennæ nearly as long as the body. Lamina a trifle longer than rostrum,

broad, greatest width at the middle, thence tapering to the long spine at apex. Third maxillipeds hairy within and below. Anterior process of epistoma truncate at apex. Chela broad, depressed, smooth and punctate below, ciliate-punctate above, margined on the outer edge. Inner margin of hand short, with a double row of small ciliated tubercles. Fingers of moderate length, straight, corneous and incurved at tip, costate and punctato-ciliate above. Movable finger with outer edge furnished with a double row of ciliated tubercles on basal half. Outer finger hairy below at base of inner side. Carpus tuberculate above, with a strong and acute internal median spine, and a minute one at the base; smooth below, with two prominent anterior spines. Third pair of legs hooked. First pair of abdominal appendages articulated near the base, long, stout, strongly curved, bifid for a short distance from tip, rami divergent, outer one the longer.

Female. Annulus ventralis triangular, rounded anteriorly, posterior wall with a longitudinal sigmoid fissure. Sternum between fourth pair of legs smooth.

Length, 61 mm. Antennæ, 52 mm.

Twenty-five specimens of this species were collected for the U. S. National Museum by Mr. Edward Palmer, in a brook running into the eastern side of Red Foot Lake, near Idlewild Hotel, Obion Co., Tenn., May 30, 1882. The lot contains males of the second form, and females. The rostrum, chelæ, and antennal scale are similar to those of *C. virilis.* It differs from that species in its linear shorter areola and male appendages, which are more strongly curved and formed more on the pattern of the same parts in *C. immunis.* In the latter species, however, these appendages are still more strongly curved, the areola is not linear in any part, the rostrum is more deeply excavated, longer, and (usually) toothless, the antennal scale is subtruncate at the end, and the hand different. Its closest relative is *C. Mississippiensis.* See description of that species.

Some of the specimens still show spots of dark color (purplish) on the chelæ, carpus, and branchial regions of the carapace. In a few specimens there is a very faint indication of a median carina on the rostrum.

15. C. Alabamensis, sp. nov.

Male, form I. Rostrum broad, punctate, sub-excavated above at base, with a broad, rounded, slightly elevated median carina near the tip, sides sub-parallel, punctato-ciliate; acumen long, triangular, marginal spines slightly developed. Anterior spine of post-orbital ridge

hardly developed. Carapace smooth, punctate, cervical groove sinuate, with minute lateral and branchiostegal spines; anterior margin notched at base of antennæ; areola wide, short (less than one half as long as the distance from cervical groove to the lateral rostral spines), thickly punctate. Abdomen longer than the cephalo-thorax by the length of the terminal segment of telson. Telson rounded behind, basal segment bispinous. Epistoma triangular. Antennæ nearly as long as the body, slender; scale moderately broad, broadest in middle, thence tapering to the apical spine. Third maxillipeds hairy within and below. Chelipeds of moderate length, strong. Chela broad, thick, hand punctate, inner margin of moderate length, scarcely serrate; fingers of moderate length, costate, ciliate-punctate, usually meeting only through their distal third. Immovable finger heavily bearded at base within, both above and below. Carpus smooth, punctate above; on the internal border there is a strong median spine, in front of this near the articulation is a minute spine, and behind it are one or two faint ones near the base; below, the carpus has a single small spine near the external articular point of the hand. Meros smooth, punctate, two obliquely-disposed spines near the anterior end of superior border; of the biserial spines beneath, only the distal one or two of the outer row are developed. Third pair of legs hooked at base. First pair of abdominal appendages long, deeply bifid, rami slender, recurved, parallel, inner ramus spoon-shaped at tip, outer ramus a little longer than the inner, compressed laterally, tapering to a fine point at tip.

Male, form II. Lateral rostral spines a little more prominent, hand smaller, hooks on third legs less strongly developed, first abdominal appendages thicker, bifid for only a short distance from the tip, rami laterally compressed, blunt-pointed.

Female. Rostrum as in the second form of the male, hand shorter and wider. Annulus ventralis with well-marked tranverse fossa.

Measurements of a male, form I.: — Length, 55 mm. Carapace, 25 mm. Abdomen, 30 mm. Length of antennæ, 50 mm. Length of areola, 7 mm. Breadth of areola, 2.5 mm. Length of chela, 21 mm. Breadth of chela, 9 mm. Length of movable finger, 12.5 mm.

A female of the same size has the areola 3 mm. in width, 7 mm. in length.

Forty specimens, including both forms of the male and the female, were collected by C. L. Herrick in Second Creek, Waterloo, Lauderdale Co., Ala., for the U. S. National Museum. The male appendages are very like those of *C. Mississippiensis*, the rami being longer and less strongly recurved than in *C. immunis*. It is at once distinguished by

its broad and short areola from the other species in which the first abdominal appendages are formed after the pattern of those of *C. immunis.* The section of the carapace behind the cervical groove is very short in this species, and the dense beard at base of the external finger is very characteristic. In *C. compressus* the areola, although broad, is long, and the strong lateral compression of the body, different form of the chela, &c., distinguish it at a glance from this species.

16. C. COMPRESSUS, sp. nov.

Male, form I. Rostrum narrow, excavated, curved downwards, with a longitudinal median carina; margins thickened, converging, with a line of ciliated dots; acumen long, triangular, with acute lateral spines at base which are obsolescent in the largest specimens. Cephalothorax strongly compressed laterally. Post-orbital ridges armed with acute anterior spines. Carapace punctate on both the back and sides; on the gastric region the punctation is very coarse, assuming the form of reticulation; cervical groove sinuate; no lateral or branchiostegian spines; anterior lateral margins notched behind the antennæ; areola broad, heavily punctated. Abdomen about the length of the thorax. Telson long, proximal segment bispinose on each side. Antennæ slender, shorter than the body by the length of the telson. Antennal scale of moderate width, terminal spine very long, reaching beyoud the tip of the rostrum. Epistoma triangular. External maxillipeds hairy within and below. Chelipeds short, stout; chelæ very large, broad, non-tuberculate, hand convex above and below, punctate, internal margin entire; fingers short, thick, with lines of ciliated dots. Carpus punctate above, with one internal median spine. Upper border of meros with one or two ante-apical spines; the biserial spines below are not devoloped, except the distal one of each row, and even these are minute. Third segment of third pair of legs hooked. First pair of abdominal appendages reach the base of the second pair of legs. They are deeply bifid, the rami recurved; the outer ramus is aciculate, the inner is enlarged at base and at tip, and the tip is furthermore grooved in front and rounded off at the end.

Male, form II. Hand smaller, fingers gaping at base, external finger ciliated at base within, hook on third segement of third legs very small; first pair of abdominal appendages articulated near the base, thick, inner and outer parts separated for only a very small distance from apex, compressed from side to side, tips a little recurved, blunt-pointed.

Female. Chelæ somewhat smaller than in the first form of the male, fingers less widely separated at base, external finger ciliated at base within. Anterior border of annulus ventralis nearly obliterated in the median line, lateral borders raised into prominent tubercles, transverse fossa wide.

Length of body (male, form I.), 45 mm. Length of carapace, 22.5 mm. Length of areola, 8 mm. Breadth of areola, 2 mm.

In the largest specimen seen, the dimensions of which are given above, the lateral spines of the rostrum are obsolete, the margins simply notched at base of the acumen; in the other specimens the lateral rostral spines, though small, are evident; the antennæ in the larger specimens are shorter in proportion to the length of the body.

Thirty-nine specimens (eighteen males, form I., two males, form II., and nineteen females) were collected by C. L. Herrick for the U. S. National Museum in Second Creek, Waterloo, and in Cyprus Creek, Lauderdale Co., Ala., October, 1882.

A small species with first abdominal appendages of the male similar to those of *C. immunis*. It is readily distinguished from all the other species with similar male appendages by the lateral compression of the cephalo-thorax, form of the chela, &c.

17. C. Sanbornii, sp. nov.

Male, form I. Rostrum long, of moderate width, excavated, margins sub-parallel, lateral spine short, acute, brown-horny, acumen long, triangular, acute. Post-orbital ridges sulcate without, with acute anterior spines; carapace oval, flattened on the back, punctate, lightly granulate and ciliate on the sides; antero-lateral margin notched behind the antennæ; cervical groove sinuate, interrupted on the sides just above the small acute lateral spine; areola of moderate width, punctate, dilated anteriorly and posteriorly. Abdomen as long as the body; posterior border of telson rounded, posterior border of basal segment bispinose on each side. Basal segment of antennule armed with an acute spine on internal border of lower side, near the apex. Antennæ as long as the body, a small acute spine on the external side of second segment; scale a little longer than the rostrum, of moderate width, widest toward the middle, thence tapering to the acute terminal external spine. Anterior process of epistoma truncate in old specimens. Third pair of maxillipeds hairy within. Chelipeds short, chela broad, punctate above and below, inner margin with a double row of depressed squamous tubercles; all the puncta and tubercles of the hand give rise to pencils of fine downy cilia;

fingers costate, punctate and ciliate, outer margin of movable finger furnished with low ciliate tubercles. Carpus broad, obliquely truncate, punctate and ciliate above, with a median internal spine; beneath, the carpus has an acute median anterior and a small external spine. Superior border of meros armed with two obliquely placed ante-apical spines; beneath ciliate; of the outer row of biserial spines only the distal spine is developed. Third segment of third pair of legs hooked. First pair of abdominal appendages short, somewhat twisted, bifid at apex; rami short, thick, of nearly equal length, outer one sharp-pointed, brown-horny, inner one curved outwards and then inwards, flattened at apex.

Length, 69 mm.

Male, form II. First abdominal appendages articulated near the base, scarcely bifid, inner and outer parts thicker than in first form, tips blunt, not brown-horny.

Female. Annulus ventralis depressed, anterior wall not prominent, posterior wall projecting backwards, a sinuous longitudinal fissure, transverse fossa obliterated.

Smoky Creek, Carter Co., Ky., and Oberlin, O.

Very closely related to *C. propinquus*, but differs as follows: the rostrum is never carinate, the chela is pubescent, the inferior median anterior spine of the carpus is well developed; the first abdominal appendages, though very near those of *C. propinquus*, have the apical part shorter and less deeply bifid. These variations may perhaps be deemed of varietal rather than of specific value; but, aside from these specimens, I have seen so little variation in the very large number of *C. propinquus* examined, that I have decided to give the present form a special name.

I have examined many specimens, including the two forms of the male, females, and young, collected by the late F. G. Sanborn in Carter Co., Ky., and by Prof. B. F. Koons at Oberlin, O.

Small individuals closely resemble young specimens of *C. propinquus*, *C. affinis*, and more closely *C. Putnami;* but the young of the first may be distinguished by the carinated rostrum; of the second, by the longer rostral acumen, antennal scale, and anterior spine of post-orbital ridge, by the longer hand and internal carpal spine, and by the divergent tips of the first pair of abdominal appendages in the male; of the third, by the longer-spined antennal lamina, the long, deeply-cleft abdominal appendages of the male, and the annulus ventralis of the female, which has a transverse fossa and bituberculate anterior wall.

One small specimen presents an interesting hermaphroditic condition. With the first abdominal appendages of the male is combined a well-formed annulus ventralis of the female!

18. C. Harrisonii, sp. nov.

Male, form I. Rostrum long, narrow, deflexed, excavated; margins thickened, a little convergent; acumen of moderate length, triangular, acute; marginal spines short, obtuse, often obsolescent. Carapace flattened above, coarsely punctate, granulate on the sides; post-orbital ridges prominent, sulcate without, with acute anterior spine; antero-lateral margin notched at base of antenna; cervical suture not sinuate, interrupted on the side; lateral spine small, acute; branchiostegian spine obsolete; areola at least one half as long as the distance from the tip of the rostrum to the cervical groove, of moderate width, punctate, the dots tending to a biserial arrangement in the middle portion. Abdomen as long as the cephalo-thorax; telson long, posterior margin rounded, posterior margin of basal segment bispinous on each side. Basal segment of antennule with an internal, sub-apical, inferior spine. Antennæ as long as the body; second segment armed with a short, acute, external spine; scale as long as the rostrum, of moderate width, widest near the middle, thence tapering to the acute external, apical spine. Anterior process of epistoma with convex sides, apex blunt or truncate. Third pair of maxillipeds hairy within. Chelipeds of moderate length, thick; chela large, broad, coarsely punctate above and below, inner margin of hand with two or three rows of depressed ciliate tubercles; fingers costate and punctato-lineate, gaping, inner margins with rounded tubercles; movable finger incurved; carpus punctate above, armed with an acute median internal spine and two inferior spines (a large median and a minute external). In some specimens there are one or two small antennal basal tubercles. Meros smooth without, two obliquely-disposed superior sub-apical spines; of the biserial inferior spines only a few of the distal ones in each row are developed. Distal end of second pair of legs ciliate. Third segment of third pair of legs hooked. First pair of abdominal appendages short, reaching to the base of third pair of legs, thick, split for a short distance from the tip; outer part longer than the inner; tips recurved, brown-horny.

Female. Fingers less widely gaping, outer one ciliate within at base. Abdomen broader. Sternum between fourth thoracic legs, smooth. Annulus ventralis a transverse ridge, thickest in the middle, where there is a rounded tubercle divided longitudinally by a sinuous

groove. Between the ridge and the sternal plates of the fourth pair of legs there is a deep transverse fossa.

Measurements of a male, form I.: — Length of body, 60 mm. Length of carapace, 30 mm. Length of abdomen, 30 mm. From end of rostrum to cervical suture, 20 mm. From cervical suture to posterior border of carapace, 10 mm. Length of rostrum, 10 mm. Breadth of rostrum at base, 4 mm. Length of rostral acumen, 3 mm. Width of areola, 1.5 mm. Length of antennæ, 60 mm. Length of chela, 25 mm. Breadth of chela, 12 mm. Length of movable finger, 17 mm. Internal border of hand, 7 mm.

In one specimen, a male, form I., the fingers are very much elongated, not gaping at base. The length of the internal border of the hand in this specimen is 7.5 mm.; the length of the movable finger, 21 mm.

Irondale, Mo. Collected by E. Harrison.

This species resembles *C. rusticus* in its general form. The male appendages, as well as the annulus ventralis of the female, however, are very different from those of any previously described species. The male appendages approach in form those of *C. propinquus* more nearly than any other, but in that species these appendages are more deeply bifid, and not recurved.

The second form of the male is unknown.

19. C. Putnami, sp. nov.

Male, form I. Rostrum broad, sub-excavated, margins nearly parallel, with a line of ciliated puncta; acumen long, equal in length to the width of base of rostrum, narrow, acute, with a black, horny tip and lateral spines. Post-orbital ridges sulcate on external side, inflated at posterior end, armed with a sharp, horny-tipped anterior spine. Carapace long-oval, slightly flattened above, heavily punctated, sides rough with ciliated granules; cervical groove deep, lightly sinuate, broken on the sides just above the small, acute lateral spine; branchiostegian spine slightly developed; anterior lateral margins angulated, but without sub-orbital spine. Posterior segment of carapace equal in length to one half the distance from tip of rostrum to cervical groove. Areola of moderate width, punctated. Abdomen as long as cephalo-thorax, pleuræ punctate, telson bispinose on each side. Anterior process of epistoma ciliated, triangular, sides convex, marginated. Basal segment of antennule armed below with an internal ante-apical spine. Antennæ slender, about as long as the body, scale as long as the rostrum, of moderate width, external border inflated,

ending in a sharp spine. Third maxillipeds hairy within and below. Chelipeds stout; chela large, external margin convex; hand ciliato-punctate above and below (the dots large), swollen above, internal border of moderate length and furnished with two or three rows of depressed ciliate tubercles; fingers gaping at base, at least in large individuals, costate and punctate-lined, external margin of movable finger with depressed ciliated tubercles irregularly disposed in two rows; tips of fingers incurved, horny. Carpus smooth or faintly tuberculate above, a large, acute median internal spine, and small proximal and distal internal spines; beneath, the carpus has a very minute or no median anterior spine, a short and acute external spine. Meros with two superior, obliquely placed ante-apical spines; of the ordinary biserial inferior spines only the distal one or two of the outer row are developed. Third pair of legs hooked on third segment. Thoracic sterna hairy. First pair of abdominal appendages very long, reaching the base of the chelipeds when the abdomen is flexed, tuberculated on internal border at the base, deeply bifid, rami slender, acute, forming an acute angle with the basal part, the outer slightly recurved, the inner shorter, incurved, and a little dilated before the tip; a projecting angle or shoulder on the anterior border at base of rami.

Male, form II. Chela smaller, fingers not gaping, hook on third segment of third pair of legs smaller; first pair of abdominal appendages split only half as far down as in the first form, rami much thicker, no projecting angle on the anterior border; these appendages are as long as in the first form, reaching forward to the base of the chelipeds; they are articulated near the base.

Female. Chela shorter and wider, external finger bearded within at base; sternum between fourth pair of legs non-tuberculate, lightly ciliate. Annulus ventralis large, transverse fossa broad and deep, anterior border bituberculate.

Measurements of a male, form I.: — Length of body, 73 mm. Length of carapace, 36 mm. From tip of rostrum to cervical groove, 24 mm. From cervical groove to hind border of carapace, 12 mm. Length of rostrum, 11 mm. Breadth of rostrum at base, 4.5 mm. Length of acumen of rostrum, 4 mm. Width of areola, 2.5 mm. Length of abdomen, 37 mm. Length of chela, 34 mm. Breadth of chela, 14 mm. Length of movable finger, 22 mm.

Known localities. Kentucky: Grayson Springs, Grayson Co.; Green River, near Mammoth Cave; Cumberland Gap.

M. C. Z., Cat. No. 3574 (young female), from Knoxville, Tenn.,

Walter Faxon, and Cat. No. 3575 (male, form II.), from Bradford, Ind., A. S. Packard, Jr., probably belong to this species, but the specimens are too young to determine with confidence.

This species resembles *C. spinosus*, from which it is easily distinguished by the length of the posterior section of the carapace, and by the length of the male appendages. From *C. affinis* it may be separated by the different form of the male appendages and female annulus ventralis, and by the single lateral spine of the carapace. I have seen males of the first form only 34 mm. in length.

20. C. forceps, sp. nov.

Male, form I. Rostrum narrow, excavated, faintly carinated in the middle; margins divergent at the base, thickened, dotted-lined; acumen long and narrow, horny tipped; lateral spines small. Post-orbital ridges not very prominent except anteriorly, where they terminate in a spine with a corneous tip. Carapace cylindroidal, punctate above, granulated on the sides, antero-lateral margins bluntly angulated; cervical groove sinuate; small and acute lateral spine: no branchiostegian spine; areola of moderate width, punctate. Abdomen as long as the cephalo-thorax: telson rounded behind, bispinose on each side. Epistoma smooth, anterior process triangular, in some specimens truncate. Thoracic sterna with silky setæ at bases of the legs. Antennæ slender, as long as the body; scale a little longer than the rostrum, of moderate width, sub-truncate at distal end, outer margin ending in a long, sharp, somewhat outwardly directed spine. Third pair of maxillipeds hairy within. Chelipeds short, stout; chelæ large, wide, with slender cylindrical, widely-gaping fingers, which are curved outward at the base and opposable only at their tips; hand thickly punctated above and below, inner margin obscurely serrate; fingers naked at base, with parallel rows of ciliated dots; a dark band around both the inner and outer fingers a little distance from the tip. Carpus punctate above, a strong, sharp internal median spine; below there is no anterior median spine, and only a very minute external one. Meros short; of the biserial inferior spines only the distal one in each row is usually developed to any extent; above there are commonly two obliquely placed ante-apical spines, in some specimens only one. Distal portion of the following pairs of legs furnished with long setæ, especially long on the second pair of legs. Third segment of third pair of legs hooked. First pair of abdominal appendages long, deeply bifid, rami slender, straight, parallel, the outer a little longer than the inner, and a little recurved at the tip. In some specimens the anterior border at the

base of the rami has a projecting angle or shoulder, but in most specimens this is not evident.

Female. Fingers straighter. Base of external finger has a dense beard on the inside; in a few of the specimens seen the fingers are longer, nearly straight, their opposed margins almost meeting throughout their length. Annulus ventralis bilaterally symmetrical, anterior margin bituberculate, posterior margin unituberculate, fossa transverse.

Dimensions of a male, form I.: — Length of body, 38 mm. Length of carapace, 19.5 mm. Length of abdomen, 18.5 mm. From tip of rostrum to cervical groove, 14 mm. From cervical groove to posterior border of carapace, 6 mm. Length of rostrum, 5 mm. Length of acumen of rostrum, 2 mm. Width of areola, 1 mm. Length of antenna, 36 mm. Length of chela, 16 mm. Breadth of chela, 7.5 mm. Length of movable finger, 10.5 mm.

The largest female specimen is 60 millimeters in length.

Cyprus Creek, Lauderdale Co., Ala.

Nine specimens, four males of the first form and five females, collected by C. L. Herrick for the U. S. National Museum, October, 1882.

This is a small species with large hand, slender fingers widely separated at base and meeting only at the tips. In the female, there is a heavy beard at base of external finger on the inner side.

In the summer of 1872 I collected in a brook at Knoxville, Tenn., six specimens, three second form males and three females, which closely resemble those obtained by Mr. Herrick in Alabama, and belong, I think, to the same species. The external finger of the males is densely bearded within at the base, as in the females from Lauderdale Co., Ala., the first abdominal appendages reach forward to the base of the second pair of legs, are bifid at the tip, the internal and external parts are thick, blunt at the tip, the outer somewhat longer than the inner, and slightly recurved at the tip.

§ 5. *Second and third pairs of legs of male hooked.*

21. C. Shufeldtii, sp. nov.

Male, form I. Rostrum plane above, margins a little convergent, raised into a slight rim from the base to the lateral spines, which are prominent and acute; acumen of moderate length, acute, pubescent. Post-orbital ridges with anterior spines. Carapace smooth, a sharp spine on the cervical groove on each side; sub-orbital angle prominent, branchiostegian spine present. Areola of moderate breadth. Telson bispinous on each side. Epistoma triangular. Antennal scale broad.

Hand smooth, cylindrical, inflated; fingers slender, incurved at the tips. Carpus smooth, armed with a single spine on the antero-inferior border. Meros provided with a single spine near the distal end of the superior margin and two or three below. Third segment of second and third pairs of legs hooked. First pair of abdominal appendages straight, bifid, inner part ending in a straight, acute tip, outer part split at the tip into two straight acute points.

In the second form of the male the hooks upon the thoracic legs are very slightly developed, and the first abdominal appendages are less deeply cleft, with blunter and less finished tips. The chela is shorter.

In the female the chela is much shorter, broader, and less cylindrical, the abdomen broader. Annulus ventralis a transverse curved ridge, the hind side of the ridge concave.

Length, 19 to 27 mm.

Locality. Near New Orleans, La.

Found with *C. Clarkii* in the collection made by Dr. R. W. Shufeldt, U. S. A., in 1883, now in the U. S. National Museum.

This is a minute species closely related to *C. Montezumæ* from Mexico. Like that species, it has the *second and third* pairs of legs hooked in the male, a condition which normally obtains in no other species known.* *C. Shufeldtii* is distinguished from *C. Montezumæ* by the presence of a lateral spine on the carapace and by the form of the male appendages. In the latter species the tips of these appendages are recurved, the inner part flattened at the end into a spoon-shaped surface. In *C. Shufeldtii* the tips of these organs are straight, and each of the three points in which they terminate is acute.

LIST OF THE KNOWN SPECIES OF CAMBARUS AND ASTACUS.

1. CAMBARUS BLANDINGII.

Astacus Blandingii, Harlan, Trans. Amer. Philosoph. Soc., III. 464. 1830. — Med. and Phys. Res., p. 229, fig. 1. 1835.

Astacus (*Cambarus*) *Blandingii*, Erichson, Arch. Naturgesch., Jahrg. XII., Bd. I., 98. 1846.

? *Astacus Blandingii*, Le Conte, Proc. Acad. Nat. Sci. Phila., VII. 400. 1855.

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* I have seen two or three abnormal specimens of *C. virilis* and *C. propinquus* with a like disposition of hooks on the legs.

Cambarus Blandingii, Hagen, Ill. Cat. Mus. Comp. Zoöl., No. III. 43, Pl. I. figs. 63, 64, Pl. III. fig. 140. 1870.

Cambarus acutus, var. B, Hagen, *op. cit.*, p. 36, Pl. III. fig. 144. 1870.

Cambarus acutus, Abbott, Amer. Nat., VII. 80. 1873 (habits).

Hab. New Jersey, Maryland, Virginia, North Carolina, South Carolina, Georgia.

a. Var. acuta.

Cambarus acutus, Girard, Proc. Acad. Nat. Sci. Phila., VI. 91. 1852.

Cambarus acutissimus, Girard, *l. c.*

Cambarus acutus, Hagen, *op. cit.*, p. 35, Pl. I. figs. 1–5, Pl. II. figs. 106, 108, 110–114, 116, 118, 120–124, 126, 127, Pl. III. fig. 143. 1870.

Cambarus acutus, var. A, Hagen, *op. cit.*, p. 36, Pl. II. figs. 107, 109, 115, 117, 119, 125.

Cambarus acutus, Forbes, Bull. Ill. Mus. Nat. Hist., No. I. pp. 3, 18. 1876.

Hab. Louisiana, Mississippi, Alabama, South Carolina, Tennessee, Missouri, Illinois, Indiana, Iowa, Wisconsin.

2. Cambarus fallax.

Cambarus fallax, Hagen, *op. cit.*, p. 45, Pl. I. figs. 103–105. 1870.

Hab. Florida.

3. Cambarus Hayi.

Cambarus Hayi, Faxon, *supra*, p. 108.

Hab. Mississippi.

4. Cambarus Clarkii.

Cambarus Clarkii, Girard, *op. cit.*, p. 91. 1852.

Cambarus Clarkii, Hagen, *op. cit.*, p. 39, Pl. I. figs. 7–10, 99, 100, Pl. II. figs. 133, 134, Pl. III. fig. 142, Pl. IV. 1870.

Hab. Texas, Louisiana, Mississippi, Alabama, Florida.

5. Cambarus troglodytes.

Astacus troglodytes, Le Conte, *op. cit.*, p. 400. 1855.

Astacus fossarum, Le Conte, *op. cit.*, p. 401. 1855.

Cambarus troglodytes, Hagen, *op. cit.*, p. 41, Pl. I. figs. 11–14, Pl. II. fig. 141. 1870.

Hab. Georgia, South Carolina.

Note. — Girard and Gibbes confounded this species with *C. Blandingii.* Gibbes distributed specimens of *C. troglodytes* under the name of *Astacus Blan-*

dingii, and the localities for *C. Blandingii* given by Girard and Gibbes probably appertain to *C. troglodytes*. The dry specimen in the Museum of Comparative Zoölogy (No. 3337) labelled "Rocky River, Olmsted, Ohio," determined as *C. troglodytes* by Hagen (*op. cit.*, p. 43), is *C. Clarkii*. The labels of dry specimens are easily transposed, and I believe this locality to be erroneous. There is an alcholic specimen of *C. troglodytes* in the same Museum (No. 197) labelled "Lawn Ridge, Ill." No other specimens have been reported from the West, and I doubt the accuracy of the locality label of this specimen. Specimens from Richmond Co., Ga., lately received from Col. C. C. Jones, Jr., approach *C. Clarkii* in the shape of the male appendages, while in the form of the rostrum and other respects they agree with *C. troglodytes*. Judging from these specimens, I believe that further explorations will break down the specific distinctions between these two forms. But my material is not sufficient for a definite opinion.

6. CAMBARUS MANICULATUS.

Astacus maniculatus, Le Conte, *op. cit.*, p. 401. 1855.

Cambarus maniculatus, Hagen, *op. cit.*, p. 52. 1870 (after Le Conte).

Hab. Lower Georgia.

Known only through Le Conte's description, which perhaps was drawn up from an immature specimen of *C. troglodytes*.

7. CAMBARUS LECONTEI.

Cambarus Lecontei, Hagen, *op. cit.*, p. 47, Pl. I. figs. 15–18, Pl. III. fig. 145. 1870.

Hab. Georgia, Alabama.

The specimens from Beaufort, N. C., and Root Pond, Miss., referred to *C. Lecontei* by Hagen, are *C. Blandingii*. Three young specimens from Pensacola, Fla. (M. C. Z., No. 249), are also placed here by Hagen, but the justice of the determination seems doubtful. They do not agree well with the types from Mobile.

8. CAMBARUS ANGUSTATUS.

Astacus angustatus, Le Conte, *op. cit.*, p. 401. 1855.

Cambarus angustatus, Hagen, p. 50, Pl. I. figs. 65–67, Pl. III. fig. 146. 1870.

Hab. Lower Georgia.

Known only through a single type specimen in the Acad. Nat. Sci. Phila.

9. CAMBARUS PUBESCENS.

Cambarus pubescens, Faxon, *supra*, p. 109.

Hab. Georgia.

10. CAMBARUS SPICULIFER.

Astacus spiculifer, Le Conte, *op. cit.*, p. 401. 1855.

Cambarus spiculifer, Hagen, *op. cit.*, p. 48, Pl. I. figs. 59-62, Pl. III. fig. 147. 1870.

Hab. Upper Georgia.

11. CAMBARUS VERSUTUS.

Cambarus versutus, Hagen, *op. cit.*, p. 51, Pl. I. figs. 55-58, Pl. III. fig. 150. 1870.

Hab. Neighborhood of Mobile, Ala. Cape Barrancas, Fla.

12. CAMBARUS ALLENI.

Cambarus Alleni, Faxon, *supra*, p. 110.

Hab. Florida.

13. CAMBARUS PENICILLATUS.

Astacus penicillatus, Le Conte, *op. cit.*, p. 401. 1855.

Cambarus penicillatus, Hagen, *op. cit.*, p. 53, Pl. I. figs. 93, 94, [95, 96?], Pl. III. fig. 149. 1870.

Hab. Georgia, Mississippi? South Carolina?

Two young female specimens from Charleston, S. C. (M. C. Z., No. 254), referred by Hagen to *C. penicillatus*, are *C. troglodytes*. Two other females, and two second form males, also from Charleston, in the same collection (No. 250), may be the female and second form of the male of *C. penicillatus*, to which they are referred by Hagen; but they differ in so many respects, that I suspect they belong to another species. In the collection of Prof. O. P. Hay of Butler University, Irvington, Ind., there is a second form male from Eastern Mississippi, which with some doubts I have referred to this species. More material must be obtained before the specific characters can be accurately given.

14. CAMBARUS WIEGMANNI.

Astacus (*Cambarus*) *Wiegmanni*, Erichson, *op. cit.*, p. 99. 1846.

? *Cambarus Wiegmanni*, Hagen, *op. cit.*, p. 54, Pl. III. fig. 151. 1870.

Hab. Mexico.

The types of Erichson's two Mexican species of *Cambarus*, *C. Wiegmanni* and *C. Mexicanus*, could not be found in the Berlin Museum, either by Hagen, who examined the collection in September, 1870, or by Von Martens (Arch. Naturgesch., 1872, p. 131). *C. Wiegmanni* alone of the known Mexican species belongs to the *C. Blandingii* group, with hooks on the third and

fourth pairs of legs in the male. The female specimen in the Acad. Nat. Sci. Phila. (No. 170, Mr. Pease), fully described by Hagen, is probably correctly referred to this species by him, although in the absence of male specimens there is some uncertainty. I have seen but one specimen of *C. Mexicanus*, a male. In this the chelæ are more cylindrical, and are covered with smaller, more closely set, granular tubercles. In the collection of Acad. Nat. Sci. Phila., I find another alcoholic female from Jalapa, Mexico, which agrees well with Mr. Pease's specimen. A mutilated female in the U. S. Nat. Mus. (No. 3288), collected by Sumichrast at the Isthmus of Tehuantepec, seems also to belong here.

15. CAMBARUS PELLUCIDUS.

Astacus pellucidus, Tellkampf, Arch. Anat. Physiol. u. wissensch. Med., 1844, p. 383.

Astacus (*Cambarus*) *pellucidus*, Erichson, *op. cit.*, p. 95. 1846.

Cambarus pellucidus, Girard, *op. cit.*, p. 87. 1852.

Cambarus pellucidus, Hagen, *op. cit.*, p. 55, Pl. I. figs. 68–71, Pl. III. fig. 148, Pl. VI. 1870.

Orconectes pellucidus, Cope, Amer. Nat., VI. 410, 419. 1872. — 3d and 4th Ann. Rep. Geolog. Surv. Ind., pp. 162, 173. 1872.

Orconectes inermis, Cope, Amer. Nat., VI. 410, 419. 1872. — 3d and 4th Ann. Rep. Geolog. Surv. Ind., pp. 162, 173. 1872.

Hab. Mammoth Cave and other caves in Edmonson Co., Ky., Wyandot Cave, Ind., and cave in Bradford, Harrison Co., Ind.

The Indiana specimens do not differ enough from the typical form from Mammoth Cave to be considered a distinct species, as Cope would have us believe. I have seen the same form from Mammoth Cave.

In the Berliner Entomologische Zeitschrift, XXVI. 12–14, April, 1882, Gustav Joseph imperfectly describes under the name CAMBARUS STYGIUS a blind Crayfish, very closely related to *C. pellucidus*, said to have come from the caves of Carniola! In the earliest notice of this startling discovery in 57th Jahresber. Schles. Gesellsch. vaterländ. Cultur, 1879, p. 202, Breslau, 1880, the new species is called *Cambarus typhlobius*. In a paper published in December, 1881, in Berliner Entomol. Zeitschr., XXV., Joseph again mentions, without describing, the animal under the names *Cambarus cæcus* (p. 237) and *C. Stygius* (pp. 241, 249). Until a more satisfactory account of this discovery

is published, one may well hesitate to admit the Carniola *Cambarus* into the list.

Cambarus Stygius, Bundy, Bull. Ill. Mus. Nat. Hist., No. I. p. 3, 1876, Trans. Wis. Acad. Sci., V. 180, 1882, Geol. Wis., Surv. 1873–1879, I. 402, 1883, a species founded on mutilated specimens (the fourth thoracic legs of the males being lost), is indeterminable. It is said to be "closely related to *C. acutus*, but may be at once separated by the shorter hands, — similar to those of *C. propinquus*, — and the non-tuberculated annulus of the female." Shore of Lake Michigan, Racine, Wis.

16. Cambarus simulans.

Cambarus simulans, Faxon, *supra*, p. 112.

Hab. Texas, Kansas.

17. Cambarus advena.

Astacus advena, Le Conte, *op. cit.*, p. 402. 1855.

Cambarus Carolinus, Hagen, *op. cit.*, p. 87, Pl. I. figs. 51–54, Pl. III. fig. 165. 1870.

Cambarus advena, Hagen, *op. cit.*, Pl. III. fig. 164, Pl. VII. 1870.

The descriptions of *C. advena* and *C. Carolinus* in Hagen's monograph are accidentally transposed, so that they do not agree with Hagen's types in the Museum of Comparative Zoölogy. A full figure of Le Conte's species is given as *C. advena* on Plate VII.,* and the antennal scale, spine of the second segment of the antenna, and epistoma (from Le Conte's type in the Philadelphia Academy) on Pl. III. fig. 164. The male appendages, antennal scale, and epistoma are figured on Pl. I. figs. 51–54, Pl. III. fig. 165, as *C. Carolinus*.

18. Cambarus Carolinus.

? *Astacus* (*Cambarus*) *Carolinus*, Erichson, *op. cit.*, p. 96. 1846.

Cambarus advena, Hagen, *op. cit.*, p. 86, Pl. I. figs. 90–92. 1870.

Cambarus Carolinus, Hagen (as determined by examination of his type specimen !).

Hab. South Carolina.

For the transposition of the descriptions and part of the figures of *C. advena* and *C. Carolinus* in Hagen's Monograph, see above. Hagen's type of *C. Carolinus*, labelled, "*Cambarus Caro-*

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* This figure represents a *female* (M. C. Z., No. 282), not *male*, as stated on the plate and in the text.

linus Er.," and described by him (p. 86) as *C. advena* Le Conte, is a first form male (M. C. Z., No. 232) from Charleston, S. C. The distinctions noted by Hagen, based on the presence or absence of spines on the lower side of the first segment of the antennule and at the end of the cervical groove, I do not find to hold good. The statement that "in the larger specimens the hand is more sulcated beneath at the inner margin, and the carpus more spinulose," probably refers to Le Conte's type of *C. advena* in the Philadelphia Academy. The female in the same jar with the male type above noticed differs from the male in so many respects that I doubt whether Hagen has correctly referred it to the same species. All the other specimens in the Museum determined as *C. Carolinus* by Hagen are small specimens. No. 3368, dry female from Georgia, L. Agassiz, is certainly *C. advena.* No. 3367 (1850 of Hagen), a young female, also from Georgia, resembles *C. advena* in most respects, but the antennal scale is too broad near the tip. No. 230, young female specimens from Mobile, Ala., and No. 275, a very young male from the same locality, appear to belong to some species allied to *C. Bartonii*, the tips of the male appendages being strongly recurved. Dr. Hagen examined Erichson's type, a male, form I., in Berlin, in 1870, and thought it was *C. Bartonii.* Erichson's description, nevertheless, fits the present species very well. The structure of the male appendages of Erichson's type would at once prove or disprove its identity with *C. Bartonii.* If it be really *C. Bartonii*, the species under consideration must receive a new name, *C. Hagenianus.*

19. Cambarus gracilis.

Cambarus gracilis, Bundy, Bull. Ill. Mus. Nat. Hist., No. I., p. 5. 1876. — Trans. Wis. Acad. Sci, V. 182. 1882. — Geol. Wis., Surv. 1873–1879, I. 403. 1883.

Hab. Wisconsin, Iowa, Illinois.

20. Cambarus Mexicanus.

Astacus (Cambarus) Mexicanus, Erichson, *op. cit.*, p. 99. 1846.

? *Cambarus Aztecus*, Saussure, Rev. et Mag. de Zool., 2e Sér., IX. 503. 1857. — Mém. Soc. Phys. Hist. Nat. Genève, XIV. 460, Pl. III. fig. 23. 1858.

Cambarus Mexicanus, Hagen, *op. cit.*, p. 84. 1870 (after Erichson).

Hab. Mexico.

I have seen one specimen (a male) in the Philadelphia Academy, which agrees with Erichson's description. It comes from

Mirador, Mexico. *C. Aztecus* Saussure has (according to the description) a shorter, flatter hand, and carpus spinous on internal border. Von Martens (Arch. Naturgesch., XXXVIII. 131) would separate it from *C. Mexicanus*. Dr. Hagen has kindly given me the following note on the types of Saussure in the Berlin Museum: "The first form of the male, and the female, from Mexico, seem to be *C. Mexicanus* Erichs., with nearly cylindrical hands. The second form, with more flattened hands, belongs alone, then, to Saussure's *C. Aztecus*. In the second form the antennal scale is more broadly truncate in front, and the rostrum is a little different, but the differences are not striking enough to preclude the identity." Erichson's types of *C. Mexicanus* were not found. Saussure's locality for *C. Aztecus* is near Tomatlan "dans les Terres-Chaudes." According to Von Martens there are specimens in the Berlin Museum from Puebla.

21. CAMBARUS CUBENSIS.

Astacus (Cambarus) Cubensis, Erichson, *op. cit.*, p. 100. 1846.

? *Cambarus consobrinus*, Saussure, Rev. et Mag. de Zool., 2e Sér., IX. 101. 1857. — Mém. Soc. Phys. Hist. Nat. Genève, XIV. 457, Pl. III. fig. 21. 1858.

Cambarus Cubensis, Hagen, *op. cit.*, p. 85. 1870 (after Erichson).

Cambarus Cubensis, Von Martens, Arch. Naturgeschichte, XXXVIII. 129. 1872.

Hab. Cuba.

Erichson's and Saussure's types are in the Berlin Museum, and have been examined by Hagen and Von Martens. Saussure's *C. consobrinus* are two dry female specimens. They differ in some unimportant regards from Erichson's *C. Cubensis*, and, as the male appendages of Saussure's species are not described, the identity of the two species is somewhat doubtful. According to Von Martens, specimens in the Berlin Museum indicate the presence of two species in Cuba. The examples of *C. Cubensis* in the Museum of Comparative Zoölogy were taken by Mr. Samuel Garman from creeks near Havana.

22. CAMBARUS BARTONII.

? *Astacus Bartonii*, Fabricius, Suppl. Entomolog. Syst., p. 407. 1798.

? *Astacus Bartonii*, Bosc, Hist. Nat. Crust., II. 62, Pl. XI. 1802.

Astacus ciliaris, Rafinesque, Amer. Monthly Mag., II. 42. Nov., 1817.

? *Astacus pusillus*, Rafinesque, *op. cit.*, p. 42.

Astacus Bartonii, Say, Journ. Acad. Nat. Sci. Phila., I. 167. Dec., 1817.

Astacus Bartonii, Harlan, Med. and Phys. Res., p. 230, fig. 3. 1835.

? *Astacus affinis*, Milne Edwards, Hist. Nat. Crust., II. 332. 1837.

Astacus Bartonii, Gould, Rep. Invert. Mass., p. 330. 1841.

Astacus Bartonii, Thompson, Hist. Vermont, Part I. p. 170. 1842.

Astacus Bartonii, De Kay, Zoöl. N. Y., Part VI., Crustacea, p. 22, Pl. VIII. fig. 25. 1844.

Cambarus Bartonii, Girard, *op. cit.*, p. 88. 1852.

Cambarus montanus, Girard, *op. cit.*, p. 88.

? *Cambarus longulus*, Girard, *op. cit.*, p. 90.

? *Cambarus pusillus*, Girard, *op. cit.*, p. 90.

Cambarus Bartonii, Hagen, *op. cit.*, p. 75, Pl. I. figs. 47–50, Pl. II. figs. 135–139, Pl. III. fig. 166. 1870.

Cambarus Bartonii, Abbott, *op. cit.*, p. 80. 1873 (habits).

Hab. New Brunswick; Province of Quebec? Maine, Vermont, Massachusetts, New York, New Jersey, Pennsylvania, Maryland, District of Columbia, Virginia, West Virginia, North Carolina, Ohio, Indiana, Lake Superior, Kentucky, Tennessee.

In the Museum of Comparative Zoölogy are specimens of *C. Bartonii* labelled, "Osage River, G. Stolley" (No. 183); but this locality is marked by Dr. Hagen as being very doubtful. Another specimen (No. 3358) is ticketed, "Charleston, S. C.?" and three specimens (No. 1101) in the same jar with an *Alpheus* are marked, "Pico, Azores, Miss O. Dabney, May 23, 1860." The latter locality, at any rate, is doubtless erroneous. Hagen states that he has seen a specimen from Georgia, and I find in the collection of the Boston Society of Natural History this species in the same bottle with a *Pagurus* and *Hyas coarctatus*, labelled, "Savannah, Ga., Dr. H. Bryant." The presence of the marine forms, especially the Northern *Hyas*, casts doubt on the correctness of the label.

As might be expected of a species with such a wide geographical range, *C. Bartonii* presents many variations of form.

23. CAMBARUS ROBUSTUS.

Cambarus robustus, Girard, *op. cit.*, p. 90. 1852.

Cambarus robustus, Hagen, *op. cit.*, p. 80, Pl. III. fig. 167. 1870.

Hab. Neighborhood of Toronto, Province of Ontario; New York, Maryland, Virginia, Illinois.

24. CAMBARUS ACUMINATUS.

Cambarus acuminatus, Faxon, *supra*, p. 113.

Hab. Saluda River, South Carolina; Western North Carolina.

25. CAMBARUS LATIMANUS.

? *Astacus* (*Cambarus*) *Bartonii*, Erichson, *op. cit.*, p. 97. 1846.

Astacus latimanus, Le Conte, *op. cit.*, p. 402. 1855.

Cambarus latimanus, Hagen, *op. cit.*, p. 83, Pl. I. figs. 43–46, Pl. III. fig. 162. 1870.

Hab. South Carolina, Georgia, Alabama, Mississippi, Tennessee (*var.*).

Erichson's types of *C. Bartonii* were examined by Dr. Hagen in 1870, and judged to be *C. latimanus*.

26. CAMBARUS DIOGENES.

Cambarus Diogenes, Girard, *op. cit.*, p. 88. 1852.

Cambarus obesus, Hagen, *op. cit.*, p. 81, Pl. I. figs. 39–42, Pl. III. fig. 163, Pl. IX. 1870.

Hab. New Jersey, Maryland, District of Columbia, Virginia, North Carolina, Ohio, Indiana, Illinois, Michigan, Wisconsin, Iowa, Missouri, Kansas, Colorado, Wyoming, Arkansas, Kentucky? Mississippi.

The labels of specimens, probably types, of *C. propinquus* and *C. Diogenes*, in the Philadelphia Academy, have been transposed.

Var. Ludoviciana.

Hab. Louisiana.

This variety, received from New Orleans, differs in having a narrower rostrum, with parallel margins, and more acute tip.

The burrowing habits of *C. Diogenes* are described by Girard, *l. c.*, and recently by R. S. Tarr in Nature, XXX. 127, and C. C. Abbott in Amer. Nat., XVIII. 1157. The curious "chimneys" at the mouth of the burrows are figured by Audubon, Birds of America, Pl. 360, 370 (4to ed.).

27. CAMBARUS ARGILLICOLA.

Cambarus argillicola, Faxon, *supra*, p. 115.

Hab. Toronto, Province of Ontario; Michigan, Indiana, Louisiana? North Carolina?

28. CAMBARUS DUBIUS.

Cambarus dubius, Faxon, *supra*, p. 114.

Hab. Mountain region of West Virginia, Virginia, and Tennessee.

29. CAMBARUS NEBRASCENSIS.

Cambarus Nebrascensis, Girard, *op. cit.*, p. 91. 1852.

Cambarus Nebrascensis, Hagen, *op. cit.*, p. 83. 1870 (after Girard).

Hab. Fort Pierre, Dakota.

This species is unknown to me. Possibly it is a form of *C. Diogenes.*

30. CAMBARUS UHLERI.

Cambarus Uhleri, Faxon, *supra*, p. 116.

Hab. Lowlands of Maryland.

31. CAMBARUS EXTRANEUS.

Cambarus extraneus, Hagen, *op. cit.*, p. 73, Pl. I. figs. 88, 89, Pl. III. fig. 156. 1870.

Hab. Tennessee River, near the border of Georgia; Etowah River, Rome, Georgia.

The larger female mentioned by Hagen, p. 74, is *C. spinosus* Bundy.

32. CAMBARUS GIRARDIANUS.

Cambarus Girardianus, Faxon, *supra*, p. 117.

Hab. Cyprus Creek, Lauderdale Co., Alabama.

33. CAMBARUS JORDANI.

Cambarus Jordani, Faxon, *supra*, p. 119.

Hab. Etowah River, Rome, Georgia.

34. CAMBARUS CORNUTUS.

Cambarus cornutus, Faxon, *supra*, p. 120.

Hab. Green River, near Mammoth Cave, Kentucky.

35. CAMBARUS HAMULATUS.

Orconectes hamulatus, Cope and Packard, Amer. Nat., XV. 881, Pl. VII. figs. 1, 1 *a*, 1 *b*. Nov., 1881.

Hab. Nickajack Cave, Tennessee.

I am indebted to Prof. A. S. Packard for the opportunity to examine six type specimens (four males, form II., and two females) of this interesting blind species.

36. CAMBARUS MEDIUS.

Cambarus medius, Faxon, *supra*, p. 121.

Hab. Irondale, Missouri.

37. CAMBARUS IMMUNIS.

Cambarus immunis, Hagen, *op. cit.*, p. 71, Pl. I. figs. 101, 102, Pl. III. fig. 160, Pl. VIII. fig. b. 1870 (male, form I., and female).

Cambarus immunis, Forbes, *op. cit.*, pp. 4, 19. 1876 (male, form II., and young).

Cambarus immunis, Bundy, Proc. Acad. Nat. Sci. Phila., 1877, p. 171.

Cambarus signifer, Herrick, 10th Ann. Rep. Geolog. Surv. Minn., p. 253. 1882.

Hab. New York, Indiana, Illinois, Michigan, Wisconsin, Minnesota, Iowa, Missouri, Kansas, Wyoming, Alabama, and Orizaba, Mexico.

a. Var. spinirostris.

Hab. Obion Co., Tennessee.

In this form the rostrum possesses lateral spines at the base of the acumen.

38. CAMBARUS MISSISSIPPIENSIS.

Cambarus Mississippiensis, Faxon, *supra*, p. 123.

Hab. Eastern Mississippi.

39. CAMBARUS PALMERI.

Cambarus Palmeri, Faxon, *supra*, p. 124.

Hab. Obion Co., Tennessee.

40. CAMBARUS ALABAMENSIS.

Cambarus Alabamensis, Faxon, *supra*, p. 125.

Hab. Lauderdale Co., Alabama.

41. CAMBARUS COMPRESSUS.

Cambarus compressus, Faxon, *supra*, p. 127.

Hab. Lauderdale Co., Alabama.

42. CAMBARUS LANCIFER.

Cambarus lancifer, Hagen, *op. cit.*, p. 59, Pl. I. figs. 86, 87, Pl. III. fig. 159. 1870.

Hab. Mississippi.

Hagen's type remains unique.

43. CAMBARUS AFFINIS.

? *Astacus limosus*, Rafinesque, *op. cit.*, p. 42. Nov., 1817.

Astacus affinis, Say, *op. cit.*, p. 168. Dec., 1817.

Astacus affinis, Harlan, Med. and Phys. Res., p. 230, fig. 2. 1835.

Astacus Bartonii, Milne Edwards, *op. cit.*, II. 331. 1837.

? *Astacus* (*Cambarus*) *affinis*, Erichson, *op. cit.*, p. 96. 1846.

Cambarus affinis, Girard, *op. cit.*, p. 87. 1852.

Cambarus Pealei, Girard, *op. cit.*, p. 87. 1852.

Cambarus affinis, Hagen, *op. cit.*, p. 60, Pl. I. figs. 19–22, 81, 85, Pl. III. fig. 152, Pl. V. 1870.

Cambarus affinis, Abbott, *op. cit.*, p. 80. 1873 (habits).

Hab. New York, New Jersey, Pennsylvania, Maryland, District of Columbia, Virginia, Lake Erie, Lake Superior.

Erichson's type, a female, from South Carolina, near Greenville (Dr. Cabanis), is perhaps the closely allied *C. spinosus* Bundy. I have seen types of *C. Pealei* Girard in the Smithsonian Institution. They are large *C. affinis*, as Hagen suspected.

44. Cambarus Sloanii.

Cambarus Sloanii, Bundy, Bull. Ill. Mus. Nat. Hist., No. I. p. 24. 1876. — Proc. Acad. Nat. Sci. Phila., 1877, p. 172.

Hab. Indiana, Kentucky.

45. Cambarus propinquus.

Cambarus propinquus, Girard, *op. cit.*, p. 88. 1852.

Cambarus propinquus, Hagen, *op. cit.*, p. 67, Pl. I. figs. 34–38, Pl. III. fig. 153. 1870.

Hab. Toronto, Province of Ontario; Montreal, Province of Quebec; New York, Indiana, Illinois, Michigan, Lake Superior, Wisconsin, Iowa.

46. Cambarus Sanbornii.

Cambarus Sanbornii, Faxon, *supra*, p. 128.

Hab. Smoky Creek, Carter Co., Kentucky; Oberlin, Ohio.

47. Cambarus Harrisonii.

Cambarus Harrisonii, Faxon, *supra*, p. 130.

Hab. Irondale, Missouri.

48. Cambarus virilis.

Cambarus virilis, Hagen, *op. cit.*, p. 63, Pl. I. figs. 23–28, Pl. II. figs. 128–132, Pl. III. fig. 155, Pl. VIII. 1870.

Cambarus debilis, Bundy, Bull. Ill. Mus. Nat. Hist., No. I. p. 24. 1876. — Trans. Wis. Acad. Sci., V. 181. 1882. — Geol. Wis., Surv. 1873–1879, I. 403. 1883 (male, form II.).

Cambarus Couesi, Streets, Bull. U. S. Geolog. Geograph. Surv. Terr., III. 803. 1877.

Cambarus virilis, Herrick, *op. cit.*, p. 253. 1882.

Hab. Lake Winnipeg, Saskatchewan River, Red River of the North, Toronto, and Montreal (?), Dominion of Canada; Da-

kota, Minnesota, Wisconsin, Iowa, Nebraska, Wyoming, Kansas, Missouri, Illinois, Indiana, Tennessee, Texas, New York?

I have examined the types of all the authors cited in the above synonymy.

49. CAMBARUS RUSTICUS.

Cambarus rusticus, Girard, *op. cit.*, p. 88. 1852.

Cambarus rusticus, Hagen, *op. cit.*, p. 71, Pl. I. figs. 80–83, Pl. III. fig. 161. 1870.

Cambarus placidus, Hagen, *op. cit.*, p. 65, Pl. I. figs. 76–79, Pl. III. fig. 158.

Cambarus juvenilis, Hagen, *op. cit.*, p. 66, Pl. I. figs. 29–33, Pl. III. fig. 157.

Cambarus Wisconsinensis, Bundy, Bull. Ill. Mus. Nat. Hist., No. I. p. 4. 1876. — Trans. Wis. Acad. Sci., V. 181. 1882. — Geol. Wis., Surv. 1873–1879, I. 402. 1883.

Hab. Pennsylvania, Ohio, Indiana, Illinois, Kentucky, Tennessee, Lake Superior, Wisconsin, Iowa, Missouri, Texas.

Among the large amount of material before me I find so many specimens that combine characters belonging to Hagen's three species, *C. rusticus*, *C. placidus*, and *C. juvenilis*, that I am led to consider them all as varieties or forms of *C. rusticus.* A type, male, form II., of *C. Wisconsinensis*, from Racine, Wis., received from Mr. Bundy, agrees pretty closely with the form *C. placidus.*

50. CAMBARUS SPINOSUS.

Cambarus spinosus, Bundy, Proc. Acad. Nat. Sci. Phila., 1877, p. 173.

Hab. Saluda River, South Carolina; neighborhood of Rome, Georgia; Tennessee River, near border of Georgia; Lauderdale Co., Alabama.

51. CAMBARUS PUTNAMI.

Cambarus Putnami, Faxon, *supra*, p. 131.

Hab. Kentucky, Tennessee, Indiana?

52. CAMBARUS OBSCURUS.

Cambarus obscurus, Hagen, *op. cit.*, p. 69, Pl. I. figs. 72–75, Pl. III. fig. 154. 1870.

Hab. Genesee River, Rochester, New York.

53. CAMBARUS FORCEPS.

Cambarus forceps, Faxon, *supra*, p. 133.

Hab. Lauderdale Co., Alabama; Knoxville, Tennessee?

54. CAMBARUS MONTEZUMÆ.

Cambarus Montezumæ, Saussure, Rev. Mag. de. Zool., 2e Sér. IX. 102. 1857. — Mém. Soc. Phys. Hist. Nat. Genève, XIV. 459, Pl. III. fig. 22. 1858.

Cambarus Montezumæ, var. tridens, Von Martens, *op. cit.*, p. 130. 1872.

Hab. Mexico.

C. Montezumæ and *C. Shufeldtii* are small species, distinguished from all others by the presence of hooks on the third segment of the *second and third* pairs of legs in the male. Dr. Hagen has given me the following note on Saussure's types of *C. Montezumæ* in Berlin: "The types are in alcohol, male, form I., and female. In the male (young) the rostrum is nearly rounded in front. Another jar contains male, form II., and female, also from Saussure, with tridentate rostrum. The second and third pairs of legs are hooked, as is stated by Saussure." The majority of the specimens which I have seen, amounting to about seventy, have the lateral spines on the rostrum (Von Martens's *var. tridens*); but in some these spines are very small, and in others reduced to a mere angle at the base of the acumen. Six specimens in the Museum of Comparative Zoölogy from near Parras, Cohahuila, have the section of the carapace behind the cervical groove shorter, the areola much broader. These may prove to be a distinct species. Five dry specimens in the same collection come from Mazatlan. It appears from these that the genus *Cambarus* extends in Mexico to the Pacific Ocean. Other localities are the neighborhood of the city of Mexico; * Puebla; Lake San Roque, Trapuato.

55. CAMBARUS SHUFELDTII.

Cambarus Shufeldtii, Faxon, *supra*, p. 134.

Hab. Neighborhood of New Orleans, Louisiana.

56. ASTACUS (CAMBAROIDES) JAPONICUS.

Astacus Japonicus, De Haan, Crustacea of Siebold's Fauna Japonica, p. 164, Pl. XXXV. fig. 9. 1842.

Astacus Japonicus, Erichson, *op. cit.*, p. 94. 1846.

Astacus Japonicus? Kessler, Bull. Soc. Impér. Nat. Moscou, XLVIII. 364. 1874.

Hab. Japan.

The three species *A. Japonicus*, *A. Dauricus*, and *A. Schrenckii*, from Japan and the basin of the Amoor River, widely separated

* I have seen specimens from Lake Tezcoco, which is said to be salt.

from the rest of their family in geographical position, form a natural group of sub-generic value to which I have given the name *Cambaroides.* In them is found a combination of characters of *Astacus* and *Cambarus.* In the general appearance of the body, with its sub-cylindrical cephalo-thorax, and in the form of the rostrum and chelipeds, these Asiatic Astacines strikingly recall the *Cambari* of North America, and their affinity is made more evident through the hooked thoracic legs and tooth-tipped sexual appendages of the male. The hooks are situate, in all these species, on the third segment of the second and third pairs of legs, as in *Cambarus Montezumæ* and *Cambarus Shufeldtii.* In all the male examples of *Cambaroides* that I have seen (one *A. Dauricus,* three *A. Japonicus*) the first abdominal appendages are divided into two sections by a transverse suture, and furnished with short blunt teeth at the tip. I suspect the existence of two forms of the male here, as in *Cambarus,* for in the male specimen of *A. Dauricus* the hooks on the thoracic legs are strongly developed, and some of the teeth at the apex of the first abdominal appendages are brown and corneous, whilst in the three male *A. Japonicus* the hooks of the thoracic legs are weak, and the terminal teeth of the first abdominal appendages are smaller and not corneous. In *A. Schrenckii* there is a transverse tubercle behind the sternum of the penultimate thoracic somite, much as in *Astacus* proper. In *A. Dauricus* and *A. Japonicus* this transverse tubercle is hollowed out behind, but still remains closely soldered to the sternum. The first abdominal somite of the female is devoid of appendages. I have examined the branchiæ in *A. Japonicus,* and find them to agree in number and arrangement with those of *A. fluviatilis,* there being one pleurobranchia (on each side) upon the last thoracic somite, and one simple branchial filament on each of the three antecedent somites. The structure of the branchiæ and coxopoditic setæ is the same as in the true *Astaci.*

Prof. C. O. Whitman, to whom the Museum of Comparative Zoölogy is indebted for four specimens of *A. Japonicus,* informs me that during his sojourn in Japan he could not learn of the occurrence of Crayfishes in Hondo, or Niphon, the main island of the empire, all the specimens known to him coming from the island of Yesso. Kessler's specimens came from the same locality as Whitman's, viz. Hakodadi, Yesso. In Whitman's specimens, as in those described by Kessler, the hind border of the telson

shows no trace of the deep notch described and figured by De Haan.

57. ASTACUS (CAMBAROIDES) DAURICUS.

Astacus Dauuricus, Pallas, Spicilegia Zoolog., Fasc. IX. p. 81. 1772.

Dauurische Krebs, Herbst, Versuch Naturgesch. Krabben u. Krebse, II. 42. 1796.

Astacus leptorrhinus, Fischer, Bull. Soc. Impér. Nat. Moscou, IX. 467, Pl. V. fig. 1. 1836.

Astacus Dauricus, Erichson, *op. cit.*, p. 94. 1846.

Astacus Davuricus, Gerstfeldt, Mém. Acad. Impér. Sci. St. Pétersbourg, VIII. 292. 1859.

Astacus Dauricus, Kessler, *op. cit.*, p. 361. 1874.

Hab. Upper portion of the basin of the Amoor River.

58. ASTACUS (CAMBAROIDES) SCHRENCKII.

Astacus Schrenckii, Kessler, *op. cit.*, p. 363. 1874.

Hab. Lower portion of the basin of the Amoor River.

59. ASTACUS KLAMATHENSIS.

Astacus Klamathensis, Stimpson, Proc. Bost. Soc. Nat. Hist., VI. 87. Feb., 1857. — Journ. Bost. Soc. Nat. Hist., VI. 494. April, 1857.

Astacus Klamathensis, Hagen, *op. cit.*, p. 93, Pl. III. fig. 169. 1870.

Hab. Oregon, Washington Terr., British Columbia (Spence Bate); from the higher regions.

I have examined the branchiæ of *A. Klamathensis*, *A. nigrescens*, and *A. Gambelii*, of the American *Astaci*. In all of them the branchial formula is the same as in *A. fluviatilis*, there being three rudimentary branchiæ on each side of the thorax. In *A. nigrescens* the two anterior ones are short, but thick. They are more highly developed in *A. Gambelii* than in any other species of *Astacus* examined, presenting an interesting approach in structure to the perfectly developed branchia. Each of the rudimentary branchiæ is much larger than in any other species, and is jointed at a short distance from the base. At the joint there are, in the intermediate pair, two short lateral filaments; in the anterior and posterior pairs, the main stem bears one filament.

60. ASTACUS LENIUSCULUS.

Astacus leniusculus, Dana, Crust. U. S. Explor. Exped., I. 524, Pl. XXXIII. fig. 1. 1852.

Astacus leniusculus, Stimpson, Journ. Bost. Soc. Nat. Hist., VI. 493. 1857.

Astacus leniusculus, Hagen, *op. cit.*, p. 94 (after Dana and Stimpson).

Hab. Washington Terr. (lower part of Columbia River, Puget Sound).

One of Dana's types is in the Smithsonian Institution (No. 2019).

The type of ASTACUS OREGANUS Randall (Journ. Acad. Nat. Sci. Phila., VIII. 138, Pl. VII., 1839), from the Columbia River, was lost or destroyed while in the hands of the artist by whom the drawing was made, and no specimen answering to the figure or description has since been found. The figure is very faulty, as pointed out by Hagen. I am inclined to think, with Hagen, that Randall's specimen belonged to the species afterwards described by Dana as *A. leniusculus.*

61. ASTACUS TROWBRIDGII.

Astacus Trowbridgii, Stimpson, Proc. Bost. Soc. Nat. Hist., VI. 87. Feb., 1857. — Journ. Bost. Soc. Nat. Hist., VI. 493. April, 1857.

Astacus Trowbridgii, Hagen, *op. cit.*, p. 93, Pl. III. fig. 171, Pl. X. 1870.

Hab. Columbia River, near Astoria, Oregon; streams running into Shoalwater Bay, Washington Terr. (J. G. Cooper).

62. ASTACUS NIGRESCENS.

Astacus nigrescens, Stimpson, Proc. Bost. Soc. Nat. Hist., VI. 87. Feb., 1857. — Journ. Bost. Soc. Nat. Hist., VI. 492. April, 1857.

Astacus nigrescens, Hagen, *op. cit.*, p. 92, Pl. III. fig. 168. 1870.

Astacus nigrescens, Huxley, The Crayfish, p. 244, fig. 61, C, F, I, fig. 62, C, F. 1880.

Hab. San Francisco, California; Steilacoom, Washington Terr.

63. ASTACUS GAMBELII.

Cambarus Gambelii, Girard, *op. cit.*, p. 90. 1852.

Astacus Gambelii, Agassiz, Proc. Acad. Nat. Sci. Phila., VI. 375. 1853.

Astacus Gambelii, Stimpson, Journ. Bost. Soc. Nat. Hist., VI. 492. 1857.

Astacus Gambelii, Hagen, *op. cit.*, p. 90, Pl. I. figs. 97, 98, Pl. III. fig. 170, Pl. XI. 1870.

Hab. Utah, Idaho, Montana, Wyoming? California?

A. Gambelii has the most eastern range of any of the American *Astaci*. It is found in the Great Salt Lake Valley, and in the upper waters of the Snake River, Idaho. From this region it has passed over the divide into the Yellowstone Valley, and invaded the territory of the *Cambari* as far as the confluence of the Yellowstone and the Missouri. An examination of the physical geography of this region shows that the migration of a Western species into the Mississippi basin at this point is no difficult matter, the divide separating the waters of the Yellowstone from those of the Snake River being very low, hardly above the level of the ancient Yellowstone Lake.* In the U. S. National Museum are two young specimens, labelled, "Willow Creek, Oct. 9, 1872. Dr. Curtis." An added ticket reads, "Wyoming Terr.?" Willow Creek in Wyoming Territory flows into the South Fork of the Platte, another affluent of the Missouri. Girard's types are said to have come from "California"; but whether this signifies California as now limited, I cannot say. In the U. S. National Museum are some specimens marked, "Found in bottle containing specimens from Santa Barbara. Dr. Webb." It is doubtful whether these were really collected at Santa Barbara. I have seen no authentic specimens from California.

64. ASTACUS TORRENTIUM.

Cancer torrentium (Steinkrebs), Schrank, Fauna Boica, III. 247. 1803.

Astacus torrentium (Steinkrebs), Wolf, Mag. neuesten Zustand Naturkunde (Voigt), XI. 42–45, Pl. I. figs. 1, 2. 1806.

Astacus saxatilis, Koch, Deutschlands Crust. Myriap. u. Arach., Heft 7, No. 1, with fig. (Panzer u. Herrich-Schäffer's Deutschlands Insecten, Heft 140, No. 1). 1835.

Astacus tristis, Koch, *op. cit.*, Heft 7 (140), No. 2, with fig. 1835.

Astacus torrentium, Koch, *op. cit.*, Heft 36 (186), No. 24, with fig. 1841.

Astacus torrentium, Erichson,† *op. cit.*, p. 92. 1846.

Astacus saxatilis,† Erichson, *op. cit.*, p. 92.

Astacus tristis,† Erichson, *op. cit.*, p. 93.

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* See W. H. Holmes's Report on the Geology of the Yellowstone National Park, in 12th Ann. Rep. U. S. Geolog. Surv. of the Territories, for 1878, Part II. p. 56, 1883.

† Erichson had an opportunity to examine Koch's types of *A. torrentium*, *A. saxatilis*, and *A. tristis*, and notes their clear specific separation from *A. fluvi-*

Steinkrebs, Lereboullet, Comptes Rendus, XXXIII. 379. 1851.

Astacus longicornis, Lereboullet, Mém. Soc. Nat. Strasbourg, V. 2 (separate pagination), Pl. I. figs. 2–2[d]. 1858.

Astacus torrentium (Steinkrebs) (in part), Gerstfeldt, Mém. Acad. Impér. Sci. St. Pétersbourg, IX. 574, 579, 581, 584. 1859 (after Koch, Erichson, and Lereboullet).

Astacus torrentium (Steinkrebs), Klunzinger, Jahresh. Vereins vaterländl. Naturkunde Württemberg, XXXVIII. 340. 1882.

Hab. Central Europe (Bohemia, Bavaria, Würtemberg, Alsace)*.

The branchial formula of *A. torrentium* is the same as that of *A. pallipes.*

65. ASTACUS PALLIPES.

? *Astacus astacus*, Pennant, Brit. Zoöl., IV. 18, Pl. XV. fig. 27. 1777.

Astacus fluviatilis (in part), Milne Edwards, *op. cit.*, II. 330. 1837 (first "variety" noted on p. 331). — Cuvier's Règne Animal, Disciples' ed., Crust., Pl. XLIX. fig. 2.

Duhlenkrebs,† Lereboullet, Comptes Rendus, XXXIII. 376. 1851.

Astacus fluviatilis, Bell, Hist. Brit. Stalk-eyed Crust., p. 237, with cut. 1853.

Astacus pallipes, Lereboullet, Mém. Soc. Sci. Nat. Strasbourg, V. 7 (separate pagination), Pl. II., Pl. III. figs. 3–3[d]. 1858.

Astacus pallipes, var. flavus, Lereboullet, Mém. Soc. Sci. Nat. Strasbourg, V. 9. 1858.

Astacus torrentium (Steinkrebs) (in part), Gerstfeldt, *op. cit.*, p. 577. 1859.

Astacus saxatilis, Heller, Die Crust. südl. Europa, p. 217, Pl. VII. fig. 5. 1863.

? *Astacus fontinalis* (l'écrevisse à pieds blancs), Carbonnier, L'Écrevisse, p. 8. 1869.

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atilis, and their close affinity with each other. He shows that the dark color of *A. tristis* is due to a coat of adhesive mould, and dismisses the question of the specific value of the differences with the remark that the distinctions may have been more evident during life.

* *A. torrentium, A. pallipes,* and *A. fluviatilis* have been so generally confounded by European authors that the data are insufficient for definitely fixing their geographical range.

† Here considered by Lereboullet but a variety of *A. fluviatilis.*

Potamobius astacus, G. B. Sowerby, Continuation of Leach's Malacostraca Podophthalma Britanniæ, Nos. XVIII., XIX., Pl. XXXIV. fig. 1. 1875.

Astacus fluviatilis,* Huxley, *op. cit.*, *passim*, and p. 230 in particular, frontispiece and figs. 1–60. 1880.

Astacus torrentium,* Huxley, *op. cit.*, p. 296, fig. 61, A, D, G, fig. 62, A, D. 1880.

Astacus pallipes (der Dohlenkrebs), Klunzinger, *op. cit.*, p. 341. 1882.

Hab. Southern and Western Europe: Grecce, Dalmatia, Islands of Cherso and Veglia, Trieste, Italy (Heller); France; Switzerland; Alsace (Lereboullet); Spain (Huxley); England, Ireland.

66. ASTACUS FLUVIATILIS.

? *Cammarus*, Belon, De Aquatil., p. 353, fig. on p. 355. 1553.

Astacus fluviatilis, Rondelet, Univ. Aquatil. Hist., Pars II. p. 210, with cut. 1555.

Astacus fluviatilis, Gesner, Hist. Animal., Lib. IV. p. 120, with cut. 1558 (in part: Edelkrebs,† p. 122).

Cammarus, Mattioli, Comment. Dioscor. de Med. Mat., Lib. II. p. 309, with fig. 1565.

Cammarus, seu Astacus fluviatilis, Aldrovandi, De Reliq. Animal. Exang.: Moll., etc., Cap. VI. p. 127, with cuts. 1606 (in part: Krebs, Edelkrebs, p. 129).

Cammarus, seu Astacus fluviatilis, Jonston, Hist. Nat. de Exang. Aquat., Lib. IV. p. 18, Pl. II. fig. 4, Pl. III. figs. 2, 3, 4, Pl. IV. fig. 1 (fig. 2 after Aldrovandi). 1650.

Cancer macrourus; rostro supra serrato, etc., Linne, Fauna Suecica, p. 358. 1746.

Der Fluskrebs, Rösel, Insekten-Belustigung, Th. III. p. 305, Pl. LIV.–LXI. 1755.

Cancer astacus, Linne, Syst. Nat., 10th ed., I. 631, 1758; 12th ed., I. 1051, 1767.

Astacus fluviatilis, Fabricius, Syst. Entomol., p. 413. 1775.

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* Huxley leaves the question of the specific or the varietal value of the forms *A. nobilis* and *A. torrentium* (= *A. fluviatilis* and *A. pallipes*) undecided.

† Under the name *Astacus fluviatilis*, *Cammarus*, or *Gammarus*, the older authors included not only the *Edelkrebs*, or the species to which the name *A. fluviatilis* is now restricted, but also the *Steinkrebs* or *Thulkrebs*, a smaller form now known as *A. torrentium*. Indeed, it is probable that these authors confounded *A. torrentium* and *A. pallipes* under the name *Steinkrebs*.

— Spec. Insect., I. 509. 1781. — Mantissa Insect., I. 331. 1787. — Entomol. Syst. em. et aucta, II. 478. 1793. — Supplem. Entomol. Syst., p. 406. 1798.

Astacus fluviatilis, De Geer, Mém. Hist. Ins., VII., Pl. XX.-XXII. 1778.

Cancer astacus, Herbst, *op. cit.*, II. 38, Pl. XXIII. fig. 9. 1796 (in part: Edle Krebse, p. 41).

Astacus fluviatilis, Latreille, Hist. Nat. Crust. et Ins., I. 367, Pl. III. 1801; III. 33, 1801; V. 235, 1802.

Astacus fluviatilis, Bosc, Hist. Nat. Crust., II. 62, Pl. XI. fig. 2. 1802.

Cancer nobilis (Edelkrebs), Schrank, *op. cit.*, p. 246. 1803.

Edelkrebs, Wolf, *op. cit.*, Pl. I. fig. 3. 1806.

Astacus fluviatilis, Brandt and Ratzeburg, Med. Zoöl., II. 58, Pl. X., XI. 1833.

Astacus fluviatilis (in part), Milne Edwards, *op. cit.*, II. 330. 1837 (second "variety" noted on p. 331).

Astacus fluviatilis, Koch, *op. cit.*, Heft 36 (186), No. 23, with fig. 1841.

Astacus fluviatilis, Erichson, *op. cit.*, p. 90. 1846.

Astacus fluviatilis, Lereboullet, *op. cit.*, V., Pl. III. figs. 1-1[d]. 1858.

Astacus fluviatilis communis, Gerstfeldt, *op. cit.*, pp. 554, 584. 1859.

Astacus fluviatilis, Heller, *op. cit.*, p. 214, Pl. VII. figs. 3, 4. 1863.

Astacus fluviatilis (l'écrevisse à pieds rouges), Carbonnier, *op. cit.*, p. 8. 1869.

Astacus fluviatilis, Kessler, *op. cit.*, p. 257. 1874.

Astacus nobilis,* Huxley, *op. cit.*, pp. 295, 296, fig. 61, B, E, H, fig. 62, B, E. 1880.

Astacus fluviatilis (Edelkrebs), Klunzinger, *op. cit.*, XXXVIII. 342. 1882.

Hab. Russia (Baltic water-shed and small streams of the upper part of the basin of the Dnieper), Austria, Germany, France, Italy? It is also found in Denmark according to Huxley, and in the Scandinavian peninsula. It appears to have been artificially introduced into the latter. It was scarcely known in Sweden before the time of John III. (1568–1592).† From Sweden

* See first foot-note on preceding page. † Linne, Fauna Suecica, p. 358, 1746.

it has spread into Southeastern Norway.* The *Astaci* of Spain are probably all *A. pallipes*, as well as those of England and Ireland.

67. ASTACUS LEPTODACTYLUS.

Astacus leptodactylus, Eschscholtz, Mém. Soc. Impér. Nat. Moscou, VI. 109, Pl. XVIII. 1823.

Astacus leptodactylus, Rathke, Mém. Acad. Impér. Sci. St. Pétersbourg, III. 359, Pl. IV. figs. 1, 2. 1837 (separate, 1836).

Astacus leptodactylus, var. Caspia, Eichwald, Bull. Soc. Impér. Nat. Moscou, 1838, p. 148. — Fauna Caspio-Caucasia, p. 179, Pl. XXXVI. fig. 1. 1841.

Astacus leptodactylus, var. salinus, Nordmann, Obs. sur la Faune Pontique, in Demidoff's Voy. dans la Russ. Mérid. et la Crimée, Atlas, Crust., Pl. I. (No date.†)

Astacus leptodactylus, Erichson, *op. cit.*, p. 90. 1846.

Astacus fluviatilis, var. leptodactylus, Gerstfeldt, *op. cit.*, pp. 558, 584. 1859.

Astacus leptodactylus, Heller, *op. cit.*, p. 215, Pl. VII. fig. 6. 1863.

Astacus leptodactylus, Kessler, *op. cit.*, p. 249. 1874.

Hab. Russia (rivers of the Ponto-Caspian basin on the north from the Danube to the Ural Mountains and the Muchojar Hills in Western Siberia, rivers and lakes draining into the Baltic and White Sea), Caspian Sea, Austria (basin of the Danube). Artificially introduced into affluents of the Tobol River, a tributary of the Irtish, Siberia,‡ where it has rapidly multiplied.

a. Var. angulosa.

Astacus angulosus, Rathke, *op. cit.*, p. 364, Pl. IV. fig. 3. 1836.

Astacus angulosus, Erichson, *op. cit.*, p. 91. 1846 (after Rathke).

Astacus fluviatilis, var. angulosus, Gerstfeldt, *op. cit.*, pp. 563, 584. 1859.

Astacus angulosus, Heller, *op. cit.*, p. 216. 1863.

Astacus leptodactylus, var. angulosus, Kessler, *op. cit.*, p. 251. 1874.

Hab. Crimea and adjacent region.

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* G. O. Sars, Hist. Nat. Crust. d'Eau Douce de Norvège, p. 11, 1867.

† The text is dated 1840.

‡ Middendorf, Sibirische Reise, IV., Th. 2, p. 885, 1867. Kessler, *op. cit.*, p. 371.

There has lately appeared an insufficient preliminary notice, by Wladimir Schimkewitsch,* of an *Astacus* from the neighborhood of the town of Toorkistan in the valley of the Jaxartes. It is closely related to *A. fluviatilis* and *A. leptodactylus*, perhaps not specifically distinct from one of these. Schimkewitsch affirms that intermediate forms connect *A. pachypus* with *A. leptodactylus* (Government of Riazan) and *A. leptodactylus* with *A. fluviatilis* (Governments of Toola and Moscow).

68. Astacus pachypus.

Astacus pachypus, Rathke, *op. cit.*, p. 365. 1836.

Astacus Caspius, Eichwald, Bull. Soc. Impér. Nat. Moscou, 1838, p. 149. — Fauna Caspio-Caucasia, p. 181, Pl. XXXVI. fig. 2. 1841.

Astacus pachypus, Erichson, *op. cit.*, p. 91. 1846 (after Rathke).

Astacus Caspius, Erichson, *op. cit.*, p. 92 (after Eichwald).

Astacus fluviatilis, var. pachypus et Caspius, Gerstfeldt, *op. cit.*, pp. 566, 584. 1859.

Astacus pachypus, Heller, *op. cit.*, p. 217. 1863.

Astacus pachypus, Kessler, *op. cit.*, p. 254. 1874.

Hab. Brackish waters of the Caspian Sea and estuaries of rivers flowing into the Caspian and Black Seas.

69. Astacus Colchicus.

Astacus Colchicus, Kessler, Bull. Soc. Impér. Nat. Moscou, L. 2. 1876.

Hab. Upper portion of Rion River and tributaries, Asiatic Russia. It has been artificially introduced into some of the tributaries of the Upper Koor (anc. Cyrus). (Kessler.)

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* Der turkestanische Flusskrebs. (Vorläufige Mittheilung.) Von Wladimir Schimkewitsch. Zoologischer Anzeiger, VII. 339, 23 Juni, 1884.

INVESTIGATIONS ON LIGHT AND HEAT, MADE AND PUBLISHED WHOLLY OR IN PART WITH APPROPRIATION FROM THE RUMFORD FUND.

VIII.

A METHOD OF MEASURING THE ABSOLUTE SENSITIVENESS OF PHOTOGRAPHIC DRY PLATES.

BY WILLIAM H. PICKERING.

Communicated May 14th, 1884.

WITHIN the last few years the subject of dry plate photography has increased very rapidly, not only in general popularity, but also in importance in regard to its applications to other departments of science. Numerous plate manufacturers have sprung up in this country as well as abroad, and each naturally claims all the good qualities for his own plates. It therefore seemed desirable that some tests should be made which would determine definitely the validity of these claims, and that they should be made in such a manner that other persons using instruments similarly constructed would be able to obtain the same results.

Perhaps the most important tests needed are in regard to the sensitiveness of the plates. Most plate makers use the wet plates as their standard, giving the sensitiveness of the dry plates at from two to sixty times greater; but as wet plates vary quite as much as dry ones, depending on the collodion, condition of the bath, etc., this system is very unsatisfactory. Another method employed largely in England, depends on the use of the Warnerke sensitometer. In this instrument the light from a tablet coated with luminous paint just after being exposed to a magnesium light, is permitted to shine through a colored transparent film of graduated density upon the plate to be tested. Each degree on the film has a number, and, after a given exposure, the last number photographed on the plate represents the sensitiveness on an empirical scale. There are two or three objections to this instrument. In the first place, the light-giving power of the luminous tablet is liable to variations, and, if left in a warm, moist place, it rapidly deteriorates. Again, it has been shown by Captain Abney that plates sensitized by iodides, bromides, and chlorides, which may be equally sensitive to white light, are not equally affected by the light emitted by the paint; the bromides being much the most rapidly darkened, the chlorides next, and the iodides least of all. The instrument is

therefore applicable only to testing plates sensitized with the same salts.

In this investigation it was first shown that the plates most sensitive for one colored light were not necessarily the most so for light of another color. Therefore it was evident that the sun must be used as the ultimate source of light, and it was concluded to employ the light reflected from the sky near the zenith as the direct source. But as this would vary in brilliancy from day to day, it was necessary to use some method which would avoid the employment of an absolute standard of light. It is evident that we may escape the use of this troublesome standard, if we can obtain some material which has a perfectly uniform sensitiveness. For we may then state the sensitiveness of our plates in terms of this substance, regardless of the brilliancy of our source. The first material tried was white filter paper, salted, and sensitized in a standard solution of silver nitrate. This was afterward replaced by powdered silver chloride, chemically pure, — which was found to be much more sensitive than that made from the commercial chemicals. This powder is spread out in a thin layer, in a long paper cell, on a strip of glass. The cell measures one centimeter broad by ten in length. Over this is laid a sheet of tissue paper, and above that a narrow strip of black paper, so arranged as to cover the chloride for its full length and half its breadth. These two pieces of paper are pasted on to the under side of a narrow strip of glass which is placed on top of the paper cell. The apparatus in which the exposures are made consists of a box a little over a meter in length, closed at the top by a board, in which is a circular aperture 15.8 cm. in diameter. Over this board may be placed a cover, in the centre of which is a hole .05 cm. in diameter, which therefore lets through .00001 as much light as the full aperture. The silver chloride is placed at a distance of just one meter from the larger aperture, and over it is placed the photographic scale; which might be made of tinted gelatines, or, as in the present case, constructed of long strips of tissue paper, of varying widths, and arranged like a flight of steps; so that the light passing through one side of the scale traverses nine strips of paper, while that through the other side traverses only one strip. Each strip cuts off about one sixth of the light passing through it, so that, taking the middle strip as unity, the strips on either side taken in order will transmit approximately, —

1	2	3	4	5	6	7	8	9
2.0	1.65	1.4	1.2	1.0	.85	.7	.6	.5

The instrument is now pointed toward the zenith for about eight minutes, on a day when there is a bright blue sky. On taking the apparatus into the dark room, and viewing the impression by gas-light, it will be found that the markings, which are quite clear at one end, have entirely faded out by the time the middle division is reached. The last division clearly marked is noted. Five strips cut from sensitized glass plates, ten centimeters long and two and a half in width, are now placed side by side under the scale, in the place of the chloride. By this means we can test, if we wish, five different kinds of plates at once. The cover of the sensitometer containing the .05 cm. hole is put on, and the plates exposed to sky light for a time varying anywhere between twenty seconds and three minutes, depending on the sensitiveness of the plates. The instrument is then removed to the dark room, and the plates developed by immersing them all at once in a solution consisting of four parts potassium oxalate, and one part ferrous sulphate. After ten minutes they are removed, fixed, and dried. Their readings are then noted, and compared with those obtained with the silver chloride. The chloride experiment is again performed as soon as the plates have been removed, and the first result confirmed. With some plates it is necessary to make two or three trials before the right exposure can be found, but if the image disappears anywhere between the second and eighth divisions, a satisfactory result may be obtained.

The plates were also tested using gas-light instead of daylight. In this case an argand burner was employed, burning 5 cu. ft. of gas per hour. A diaphragm 1 cm. in diameter was placed close to the glass chimney, and the chloride was placed at 10 cm. distance, and exposed to the light coming from the brightest part of the flame, for ten hours. This produced an impression as far as the third division of the scale. The plates were exposed in the sensitometer as usual, except that it was found convenient in several cases to use a larger stop, measuring .316 cm. in diameter.

The following table gives the absolute sensitiveness of several of the best-known kinds of American and foreign plates, when developed with oxalate, in terms of pure silver chloride taken as a standard. As the numbers would be very large, however, if the chloride were taken as a unit, it was thought better to give them in even hundred thousands.

SENSITIVENESS OF PLATES.

Plates.	Daylight.	Gas-light.
Carbutt Transparency	.7	
Allen and Rowell	1.3	150
Richardson standard	1.3	10
Marshall and Blair	2.7	140
Blair Instantaneous	3.0	140
Carbutt Special	4.0	20
Monroe	4.0	25
Wratten and Wainwright	4.0	10
Eastman Special	5.3	30
Richardson Instantaneous	5.3	20
Walker Reid and Inglis	11.	600
Edwards	11.	20
Monckhoven	16.	120
Beebe	16.	20
Cramer	16.	120

It will be noted that the plates most sensitive to gas-light are by no means necessarily the most sensitive to daylight; in several instances, in fact, the reverse seems to be true.

It should be said that the above figures cannot be considered final until each plate has been tested separately with its own developer, as this would undoubtedly have some influence on the final result.

Meanwhile two or three interesting investigations naturally suggest themselves: to determine, for instance, the relative actinism of blue sky, haze, and clouds; also, the relative exposures proper to give at different hours of the day, at different seasons of the year, and in different countries. A somewhat prolonged research would indicate what effect the presence of sun-spots had on solar radiation, — whether it was increased or diminished.

IX.

CONTRIBUTIONS FROM THE CHEMICAL LABORATORY OF HARVARD COLLEGE.

ON THE REDUCTION OF CAMPHOR TO BORNEOL.

By C. Loring Jackson.

Communicated November 12th, 1884.

In 1883, Menke and I published a paper * entitled "A New Method of Preparing Borneol from Camphor," in which we described, first, the complete reduction of camphor to borneol by sodium and moist toluol; secondly, a convenient practical method for making borneol by the action of one and a third times the theoretical amount of sodium on an alcoholic solution of camphor, and purifying the product by crystallization from hot alcohol; and thirdly, explained the formation of the borneol by the following reaction: —

$$C_{10}H_{16}O + H_2 = C_{10}H_{18}O.$$

In the first number of the Monatshefte für Chemie † for this year, Kachler and Spitzer published an examination of our method, which led them to the conclusion that it was worthless, since in three experiments they obtained products, the larger part of which melted from 179° to 181°, and in no case higher than 185° even after fractional crystallization and sublimation (borneol melts at 199½°); while another set of experiments showed that as much as 82.8% of the hydrogen evolved by the sodium in one case, and 54.1% in another, escaped in the free state. They also determined how much borneol had been formed in one of their experiments, by converting the crude product into chlorides, and determining the chlorine, which showed 22.8% of borneol to 77.2% of unaltered camphor; and therefore doubt whether the formation of borneol was due to reduction by nascent

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* These Proceedings, Vol. XVIII. p. 93.

† Monatshefte für Chemie, No. 5, p. 50.

hydrogen at all, but ascribe it rather to the action of the sodium itself, as if in the presence of an indifferent liquid (Baubigny's reaction).

It is to be remarked, however, that they have confined their attention to the reduction of camphor by sodium and alcohol, and were not justified in thus rejecting our reaction,

$$C_{10}H_{16}O + H_2 = C_{10}H_{18}O,$$

as they had not repeated the experiment described in the beginning of our paper, in which 25 g. of camphor by the action of an excess of sodium and moist toluol were completely converted into borneol, as shown by the melting-point 197–198°, and a combustion. That this observation, and therefore the reaction given above, are correct, has been proved by Immendorff under the direction of Anschütz, who has published a most welcome paper * on the subject in the interval between the appearance of Kachler and Spitzer's paper and this answer, which has been much delayed, because, since the publication of their paper, I have had no laboratory at my disposal until this autumn. Immendorff's proof consisted in increasing the amount of sodium used upon the alcoholic solution of camphor from $1\frac{1}{3}$ to $3\frac{1}{3}$ times the theoretical amount, when he obtained a product, which, after crystallization from petroleum ether or sublimation, melted at 199–200°, and was proved to be pure borneol by analyses of its chloride. Although in this way he confirms our theoretical views, he did not obtain better results from our practical process than Kachler and Spitzer, as he got as low a melting-point (181°) as they, when he used the amount of sodium recommended by us ($1\frac{1}{3}$ times the theory), and even with twice the theoretical amount did not get a melting-point above 188°. As we had got a melting-point of 193° for the crude product, I felt that it was advisable to take up the subject again, and study the conditions of the reaction more carefully, especially as both Kachler and Spitzer and Immendorff dwell on the interest of this process from a theoretical as well as a practical point of view.

The result of my experiments is, however, that, even when in following our original directions I tried to make the conditions as unfavorable as possible, the melting-point of the crude product was 187–188°, and in other repetitions 188° and 189°, so that my products with one and a third times the theory of sodium melted 6° to 8° higher than the corresponding ones of Immendorff, and as high as his with twice the theory,† but not so high as our previous melting-point of 193°. Although,

* Ber. d. ch. G., xvii. p. 1036.

† With twice the theory I obtained melting-point 194°.

as I could not get such low melting-points as the foreign chemists, I have been unable to find the cause of the difference between their results and ours, I have succeeded in modifying the process for making borneol, so as to make it superior even to the much improved form given to it by Immendorff; for I soon found that a better result was obtained if less alcohol was used, and upon reducing the quantity by one half, that is, using five times the weight of the camphor, instead of ten times, as we advised originally, I obtained with one and a third times the theory of sodium a product * melting at 193° without purification, while increasing the sodium to twice the theory gave me the same result as Immendorff's with the larger quantity of alcohol, and three and a third times the theory, that is, a crude product having the melting-point 196°, which was not raised by the use of more sodium, and gave by one crystallization from ligroine † 52%, and in a second case 45%, of pure borneol, melting between 199° and 200°. This same melting-point was obtained in four different experiments; and that the yield was not better from Immendorff's method was proved by following his directions carefully in another experiment, the product of which gave, after treatment with ligroine, not more than 50% of pure borneol. I should judge, too, from the results of my experiments, that cooling and stirring the liquid had a favorable action on the process, but their effect is comparatively small.

The work described above has led me to the following method for the preparation of borneol from camphor, which becomes in this way one of the simplest and easiest operations in organic chemistry: — 10 g. of camphor are dissolved in 50 g. of common alcohol in a small beaker, and treated with 6 g. of sodium added in pieces of from 0.1 to 0.2 g. At first, only two pieces are added at a time, the addition of fresh sodium taking place only after what has been already put in has disappeared; but after the fourth gramme, a gramme may be added at once, cut in pieces of the size mentioned above. The object should be to keep up a gentle effervescence, and it is well to stir the liquid frequently, to keep it cool by immersing the beaker in a dish of water, and toward the end of the process, when the action has become sluggish, to add from time to time a few drops of water to prevent the liquid from becoming pasty. After all the sodium has been

* As this substance is identical with the crude product described in my paper with Menke, I am inclined to think that we must have used less alcohol than the amount recommended by us in that paper.

† The crystallization from ligroine, as recommended by Immendorff, is far superior to the crystallization from hot alcohol, used by Menke and me.

used up, the crude borneol is precipitated by water, washed till free from alkali, dried by pressure between cloth or filter-paper, and purified by crystallization from ligroine.

Finally, I would add that sodium amalgam reduces an alcoholic solution of camphor, although the action is so slow that it is of no value as a practical method, the melting-point being raised only to 183° by action during two weeks, part of the time on the water-bath. The fact however deserves mention, because in Beilstein's Handbuch, p. 1763, it is stated that sodium amalgam does not act on camphor.

X.

DICTYONEURA AND THE ALLIED INSECTS OF THE CARBONIFEROUS EPOCH.

BY SAMUEL H. SCUDDER.

Communicated December 10th, 1884.

THE recent discoveries of Mr. Charles Brongniart in the insect fauna of Commentry, France, have thrown a flood of light over the obscurities of the carboniferous epoch. Wings of a type which all writers had agreed were at any rate neuropterous, and referred to a special genus, Dictyoneura, are found by him attached to bodies which are clearly orthopterous, and of a specialized group, which one would scarcely have looked for in ancient times. Additional species now occur from time to time, and the number of forms referred to Dictyoneura is constantly growing. Others allied to them have been referred, and are still being referred, to other genera, and to still other divisions of Neuroptera.

Under these circumstances, and because a number of new American types need to be brought into their proper place, I have thought best to offer a brief synopsis of those carboniferous forms heretofore discovered, (with a few additional ones from this continent,) which may be referred to the ancient Phasmida.

Among them will be found nearly all the species heretofore referred to the Termitina from the European coal measures, for a careful study shows that the white ants were not at all represented in palæozoic times, so far as the forms yet discovered show. Most of those which have been considered Termitina belong rather here, (they have already in several instances been referred here,) while others belong to other groups of Neuroptera than Termitina.

A fuller memoir on this subject, with detailed descriptions and full illustrations, will be given at an early day.

The genera may be separated in the following manner: —

1. Wings moderately slender, scapular nervure branched . . . 2
1. Wings very slender or pointed, scapular nervure simple . . . 5

2. Wings very large, scapular vein beginning to branch in the middle of the basal half of the wing . . . . *Titanophasma.*
2. Wings generally much smaller than in the preceding genus, scapular vein first branching at, or beyond, or only a little before, the middle of the wing. (In some small species of Dictyoneura s. s. it branches unusually near the base.) 3
3. Scapular and externomedian veins first dividing near together before the middle of the wing; branches of the scapular vein arising from a single principal branch 4
3. Scapular vein first dividing beyond the middle of the wing, and usually far from the first forking of the externomedian vein; branches of the scapular vein arising from the main stem . . *Litoneura.*
4. Internomedian vein simple . . . . *Dictyoneura.*
4. Internomedian vein forked . . . . *Polioptenus.*
5. Wings triangular, much broader next the base than beyond; the tip roundly pointed . . . . *Breyeria.*
5. Wings oblong-ovate, broadest in the middle, or as broad in the middle as next the base; the tip generally rounded, but sometimes pointed 6
6. Fore wings four, or less than four, times as long as broad; branches of veins oblique, curving down to and striking obliquely the lower margin of the wing, of which margin those of the externomedian vein occupy at least one third; anal area extending nearly to the middle of the wing; no intercalary veins . . . *Goldenbergia.*
6. Fore wings five or six times longer than broad; branches, either much curved, running at first longitudinally, and then becoming very oblique, striking the margin nearly at right angles, and with many intercalary veins; or more nearly resembling Goldenbergia, and without intercalaries; in both cases with rare dichotomosis . . . . *Haplophlebium.*
6. Fore wings four, or less than four, times as long as broad; branches of veins dichotomizing strongly, and running longitudinally, so that those of the externomedian vein occupy only a slight portion of the lower margin; no intercalary veins . . . . . *Paolia.*

Titanophasma Brongniart.

This is the larger type of the two whose bodies were found by Brongniart, one measuring as much as a fourth of a metre in length. The resemblance in every essential feature of the neuration of the wing of Brongniart's type to the largest-sized wings heretofore re-

ferred to Dictyoneura, shows that the latter certainly belong here. The species may be separated thus: —

1. (Hind) wing at least fifteen centimetres long; the first offshoots of the scapular branch emitting nervules on the outer side only; extremities of nervules rather strongly arched.
T. Fayoli Brongn. Commentry, France.
1. (Hind) wing hardly more than twelve centimetres long; the first offshoot of the scapular branch emitting nervules on the inner side only; extremities of nervules rather gently arched . . 2
2. First offshoots of the scapular branch arising only a little beyond the middle of the wing, and some distance before the middle of the scapular branch; reticulation small and fine.
T. libelluloides (*Dict. libelluloides* Gold.).
Gersweiler, Auerswald (Saarbruck basin).
2. First offshoot of the scapular branch arising far beyond the middle of the wing, at about the middle of the branch; reticulation moderately large and coarse. Length 7 mm. . *T. jucunda*, n. sp.
Near Pittston, Penn. (R. D. Lacoe, No. 2027).

LITONEURA (λιτὸς, νευρά), n. gen.

Here are placed the simplest forms in all the group, in which the veins are also comparatively few, simple, and distant. Three species are known: —

1. Wings small; fore wing not more than two and a half times longer than broad 2
1. Wings large; hind wing nearly four times as long as broad.
L. laxa (*Term. laxa* Gold.). Dudweiler (Saarbruck basin).
2. Some of the veins below the externomedian forking beyond the middle of their course . . . *L. obsoleta* (*Dict. obsoleta* Gold.).
Altenwald (Saarbruck basin).
2. None of these veins forking beyond the middle of their course.
L. anthracophila (*Dict. anthracophila* Gold.).
Gersweiler (Saarbruck basin).

DICTYONEURA Gold.

In restricting this generic term, which has been applied to nearly all the European species mentioned here, I have employed it for one of the groups which contains an original member of the division, as defined by Goldenberg, and have selected the one having the largest number of species, and in which the internomedian vein is simple.

The group originally contained three species, which are here divided among the three genera so far discussed. As restricted, the species are the following: —

1. Wings exceeding seven centimetres in length; the scapular branch originating at about the middle of the wing . *D. Schmitzii* Gold. Altenwald (Saarbruck basin).
1. Wings not exceeding five centimetres in length; scapular branch originating much before the middle of the wing 2
2. Branches of scapular and externomedian veins very dissimilar; those of the latter much more numerous . . *D. Humboldtiana* Gold. Sulzbach (Saarbruck basin).
2. Branches of scapular and externomedian veins similar . . . 3
3. Main scapular branch first forking far beyond the middle of its course . . . . . . *D. sinuosa* Kliv. (Saarbruck basin.)
3. Main scapular branch first forking before the middle of its course. *D. affinis* (*Termes affinis* Gold.). Sulzbach (Saarbruck basin).

Polioptenus (πολιὸς, πτηνός), n. gen.

A single species, *Dict. elegans* Gold., from Dudweiler, in the Saarbruck basin, is separated from the others to which it is allied, on account of its forked internomedian, which has here almost the importance of the externomedian. In other respects, it agrees in general features with Dictyoneura.

Protophasma Brongniart.

It was in founding this genus that Brongniart made known the relationship of the wings allied to Dictyoneura, heretofore considered neuropterous. The wing of Protophasma, as figured by Brongniart, however, differs plainly from any of the genera here distinguished, although it seems certain that his delineation of the neuration cannot be considered strictly accurate, as it is very anomalous, and probably distorted by its preservation. We have not attempted, therefore, to place it in our table, though the position of the genus is somewhere among those in which the scapular nervure is simple. A single species is known, *Prot. Dumasi* Brongn., Commentry, France.

Breyeria De Borre.

Much discussion has arisen concerning the affinities of the single wing upon which this genus was founded, which will be found princi-

pally in the *Comptes Rendus* of the Belgian Entomological Society eight or nine years ago. De Borre at first considered it an orthopterous insect, and named it Pachytylopsis, together with another smaller form. Afterwards he separated it from the other under the above name, in maintaining Breyer's belief that it was lepidopterous. To this opinion he gained no adherents, and subsequently modified his views by calling it a member of the ancestral stock of Lepidoptera. The true position of the fossil will hardly be doubted by those who will examine the entire series here discussed. Two species are referred here: —

1. Wing scarcely more than twice as long as the greatest breadth; branches of the anal vein widely and rather abruptly divaricate . . . . . *B. borinensis* De Borre. Mons, Belgium.
1. Wing fully three times as long as the greatest breadth; branches of anal vein approximate, gently divaricate.
B. elongata (*Dict. elongata* Gold.).
Dudweiler (Saarbruck basin).

GOLDENBERGIA, n. gen.

I venture to apply the name of one of the closest students of carboniferous insects to this group, comprising, as it does, a considerable number of species first made known by him, though then supposed to belong mostly to the Termitina. It is the most prolific of the European genera. The following are the species: —

1. Wings rapidly narrowing from within the middle outward, at most scarcely more than three times as long as broad 2
1. Wings gently narrowing from about the middle outward, and more, generally much more, than three times as long as broad . . 3
2. Broadest portion of wing in the middle of the basal half, the lower margin beyond this slightly concave, making the wing falcate; veins very gently curved . *G. elongata* (*Dict. elongata* Gold.).
Dudweiler (Saarbruck basin).
2. Broadest portion of wing scarcely behind the middle, the lower margin outside of this gently convex, the apical portion of the wing not at all falcate; veins more curved than in the preceding.
G. nigra (*Dict. nigra* Kliv.). Frankenholz, Bavaria.
3. Fore wing equal throughout most of its extent; internomedian vein simple . . . . . *G. Decheni* (*Termes Decheni* Gold.).
Altenwald (Saarbruck basin).
3. Wings oblong-ovate; internomedian vein forked 4

4. (Fore) wing slender, four times as long as broad; all the branches of the externomedian vein arising beyond the middle of the wing. *G. Heeri* (*Termes Heeri* Gold.). Altenwald (Saarbruck basin).
4. (Hind?) wing comparatively stout, about three times as long as broad; the basal branch of the externomedian vein arising before the middle of the wing . *G. formosa* (*Termes formosus* Gold.). Gersweiler (Saarbruck basin).

G. Heeri and *G. formosa* are probably distinct, but may be front and hind wing of the same species.

Haplophlebium Scudder.

We come now to two groups which are distinctly American, and into which all the American species save one (a Titanophasma) enter. This separation of the minor elements of the archaic Phasmid type is not a little remarkable. The wings in this genus are excessively slender. Two species are known to me: —

1. Wings about five times longer than broad; veins regularly and gently curved, equidistant and distant; no intercalaries. *H. Barnesii* Scudd. Cape Breton.
1. Wings about six times longer than broad; veins strongly curved, especially as they approach the margin, not very distant, excepting toward the margin, and abundantly supplied with intercalaries. Length 6 mm. . . . . *H. longipennis*, n. sp. Pittston, Penn. (R. D. Lacoe, No. 2008, 2014, 2020).

Paolia Smith.

This type, first brought to light thirteen years ago, has since been enriched by several unpublished forms. The wings are graceful in shape, and the neuration more flowing than in any other of the group. The discovery of the body is greatly to be desired. Most of the following species are new: —

1. Fore wings narrower than in the other series; anal nervules straight and nearly as longitudinal as the sweep of the general mass of nervures, with no terminal forks, and reaching no farther than the middle of the wing 2
1. Fore wings broader than in the alternative series; anal nervules more oblique than the others, the outermost (always?) strongly and suddenly curved at the basal fork, at the distal end reaching along the inner border by successive forkings to beyond the middle of the wing 3

2. Wings very large, reaching a length of nine centimetres; externomedian vein beginning to fork far beyond the middle of the wing; branches of internomedian vein superior to upper fork.
   P. superba, n. sp. Mazon Creek, Ill. (L. M. Umbach).

2. Wings much smaller than the preceding, not exceeding four centimetres in length; externomedian vein beginning to fork before the middle of the wing; branches of internomedian vein terminal.
   P. Lacoana, n. sp. Near Pittston, Penn. (R. D. Lacoe, No. 2015).

3. Upper branch of internomedian vein several times forked, commencing scarcely beyond the basal externomedian fork; anal branches more ramose next margin than in the following species . . . . *P. vetusta* Smith. Paoli, Indiana.

3. Upper branch of internomedian vein forking only once, at a long distance from the basal externomedian fork; anal branches comparatively simple. Length 5.5 mm. . . . *P. Gurleyi*, n. sp.
   Orange Co., Indiana (W. Gurley).

Besides these, Brongniart mentions and names several species from Commentry, but without any exact indication of their relationship or any characterization. Facts concerning them will, doubtless, soon be forthcoming, as it is understood that he is engaged on the entire carboniferous insect fauna of Commentry.

Since presenting the above paper, Mr. Brongniart has kindly sent me drawings of the wings of his *Dict. Monyi* and *Dict. Goldenbergi*, the former an enormous wing about three decimetres long. They both fall in one genus, in the vicinity of Goldenbergia, but must be separated from that on account of the vast number of nervules, and the completely simple internomedian vein.

XI.

THE "TACONIC SYSTEM," AND ITS POSITION IN STRATIGRAPHIC GEOLOGY.

BY JULES MARCOU.

Communicated December 10th, 1884.

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I. INTRODUCTION.

De Verneuil has wittily said, that "the primordial fauna of Bohemia has made a fortune; one might also say, that the Taconic fauna in America has not made a fortune"; although Barrande's conclusion on the matter is thus stated: "Simple and impartial witness of the discussions of American geologists, we recognize in the Taconic fossils the same order of succession as that which is established in the palæozoic regions of Europe." *

The publication of this memoir will not cause all opposition to the "Taconic System" to cease. When we remember the favorite dogma of mud-currents and gigantic waves of water in the transportation of erratic boulders, and the lively and passionate opposition that was made to the glacial theory of Agassiz and to the ice age, we see that an opposition of forty years' standing is "hard to die." Though the dogma of the transportation of boulders by water has been again and again demolished for fifty years past, it every now and then reappears dressed up anew, as a fresh contribution to geological progress.

Two sorts of manifestations are made against the Taconic system which escape refutation by their intangible nature. One is, simply to

* See "Documents anciens et nouveaux sur la Faune primordiale et le Système Taconique en Amérique," par J. Barrande, pp. 225, 228, and 293 (Paris, 1861).

write the "so-called Taconic system," — this expression containing the knowledge of the writer on the question. The other is, carefully to avoid naming the Taconic, even in the manuals destined to present to the public the actual condition of American geology.

In the same way one hears geologists say, "I do not believe in the doctrine of colonies"; or, "I do not believe in the passage of one or more species from one system of strata to another." To deny facts does not suppress them. They are there, in the field, and the only answer is, that those who do not see them are unfortunate.

"Geological theories, instead of being rigid and irrevocably fixed in their principles, should be framed with great elasticity, to embrace, if need be, unexpected facts. Geology is far from being complete for us, and is slowly forming itself, surmounting the difficulties of observation, and also painfully freeing itself from the hindrances that our limited human intelligence creates for itself by preconceived theories." *

Geology is not a science to be studied in laboratories, nor by manuals; it is by work in the field, in deciphering the manuscript that the earth spreads everywhere before us, that a knowledge of it is attained; and certain more difficult pages of this terrestrial book require many years, and often several generations of geologists, to be correctly interpreted. In the end, the truth is always victorious, in spite of opposition and obscurity, and therefore the future of the "Taconic System" is fully assured.

II. Historic: 1837–1881.

1837. — The "sandstone of Potsdam" was first recognized and named by Dr. Ebenezer Emmons in 1837. In his "Second Annual Report" as Geologist of the Second Geological District of the State of New York (Albany, Feb. 15, 1838, p. 214), this name first appears, with a description of the quarries of Racket River, near Potsdam village, in the county of St. Lawrence. "Potsdam Sandstone," the designation of a group of rocks since become so celebrated in geology, was first printed on page 217 of the same Report.

1838–42. — The first appearance of the "Taconic System" is in the "Final Report on the Second District of New York" (Albany, Jan. 1, 1842), of which it constitutes Chapters VII., VIII., and IX. Dr. Ebenezer Emmons says: "A group or system of rocks which belong evidently to a position between the primary of the Atlantic

* Barrande, Défense des Colonies. IV. p. 79 (1870).

ranges of mountains and the New York system. In these remarks the writer does not expect to be able to give full justice to the subject on which he is about entering; the merit, to a certain extent, of removing some of the obscurities which envelop this system of rocks, is all that he would claim." A very modest estimate, certainly.

"The Taconic System, as its name is intended to indicate, *lies along both sides of the Taconic range of mountains*, whose direction is nearly north and south, or for a great distance parallel with the boundary line between the States of New York, Connecticut, Massachusetts, and Vermont. The counties through which the Taconic rocks pass are Westchester, Columbia, Rensselaer, and Washington; and after passing out of the State they are found stretching through the whole length of Vermont, and into Canada as far north as Quebec. It is, however, in Massachusetts, in the county of Berkshire, that we find the most satisfactory exhibition of these rocks. They form a belt whose width is not far from fifteen miles along the whole western border, and which extends clearly to the western part of the Taconic range." *

He divides the rocks composing his Taconic system into five groups, in the following ascending order: 1. Stockbridge limestone; 2. Granular quartz; 3. Magnesian slate; 4. Sparry limestone; and 5. Taconic slate. Insisting more especially on the "liability to mistake some of the slates and limestones for those which belong to other systems." Emmons demonstrates that the Taconic system is "not connected with or related to the slates and shales of the Champlain group (Utica slate and Lorrain shales)." Finally he says: "These rocks are entirely destitute of fossils"; and "appear to be equivalent to the Lower Cambrian of Prof. Sedgwick."

In the following passage Dr. Emmons gives the exact time from which dates the Taconic system: "When, in 1836, I determined that in New York the Potsdam sandstone was the base of the Silurian system, it seemed that we had at that time the base of the sediments; but when, two years subsequently, I had observed the same base resting on sediments still older, as those along the eastern side of Champlain and elsewhere, it became evident that there was still a series older than the Silurian. The proof of this has been accumulating ever since; and the Taconic system is found to rest upon primary rocks without an exception; and it has now been observed through the whole length of the States, from N. E. to S. W. It is worthy of note,

* Geology of the Second District of New York, p. 136.

that through this whole extent the base is continuous. The most northeasterly point at which I have observed this system is at the Fox Islands, off the coast of Maine; but I have good reason to suspect its existence in Newfoundland. If so, it ranks among the most persistent geological formations of this country."*

1844-46. — The quarto volume published in Albany, 1844, entitled, "The Taconic System, based on Observations in New York, Massachusetts, Maine, Vermont, and Rhode Island," is the work that has best made known this new system of rocks. Resuming his "Final Report" of 1842, Dr. Emmons here develops largely his first views, and extends them by explorations and observations throughout New England. The indication of fossils, all of them figured, is the most important part of the work, as follows: two Trilobites, *Atops trilineatus* and *Elliptocephala asaphoides*, found by Dr. Fitch near Bald Mountain, in Washington County, New York; several *Nereites* from Maine; and some *Graptolites* (fucoides) from the flagging-stone of Hoosick.

This memoir, except the Preface, is exactly reproduced in "Agriculture of New York," by Ebenezer Emmons, Vol. I. (Albany, 1844, 4to), with an Appendix of four pages. It constitutes the fifth chapter, from page 45 to page 112 inclusive.

1855-56. — Dr. Emmons gives a new statement of the documents relating to his Taconic system in his "American Geology," Vol. I. Part II. pp. 1 to 122 (Albany, 1855, 8vo). Here are a few quotations: —

"*The Taconic period one of animal and vegetal life.* — This system is not less thoroughly peculiar in its organisms than in its physical characteristics. It is true that the number of its fossils is small when compared with the Silurian period; but, as far as they go, they stamp upon it a distinctiveness which is as marked as that of the Silurian and Carboniferous. . . . As a general rule, however, the fossiliferous bands occupy nearly the same horizons, and they are so rarely absent that the palæontologist always expects to find them. It is not so, however, in the Taconic system; *there is a general barrenness of life* and vitality, which is not accounted for, unless it is regarded as due to the period in which the rocks were deposited. . . . While the Silurian carries its characteristic fossils for more than a thousand miles, the Taconic system is equally comparatively barren for the same distance. Again,

* American Geology, Part II. The Taconic System, (Albany, 1855,) pp. 5 and 6.

the scarcity of fossils cannot be explained on the ground that the rocks have not been examined. This series of rocks have been under the eyes of geologists since 1817; they have been examined minutely in Rensselaer and Washington counties, New York, and Berkshire, Massachusetts, and with more or less care over the whole area of western Vermont. A few fossils only have been discovered over this large area. Of the fossils which these rocks have furnished, marine vegetables are the most common, but they are limited to a few obscure species; the thickness of the bed in which they occur is at least 2,000 feet. Graptolites rank next in numbers; they even exceed the marine plants in the number of species which have been found. In addition to the foregoing, there are three species of Trilobites and some four or five of mollusca."

Dr. Emmons describes four marine plants, twenty-one Graptolites, six Mollusca, and three Trilobites. Of the Mollusca he says, "Most of the mollusca of this system belong to the family of Brachiopods, all of which are so minute that it is difficult to discover their most important characters." And of the Trilobites he observes, "*The species, however, are unknown in the Silurian period.*" Finally, Emmons summarizes the Taconic system in the following manner.

"The Taconic system rests, then, on the following points: —

"1. Its series, divided into groups, are physically unlike the Lower Silurian series.

"2. It supports unconformably at numerous places the Lower Silurian rocks.

"3. It is a vital system, having been deposited during the period when organisms existed.

"4. As a natural history system, it is unlike the Lower Silurian; first, in containing fossils yet unknown in the Lower Silurian; and, second, in the absence of the typical forms which are prevalent in the Lower Silurian.

"5. In the Taconic system we have the palæozoic and sedimentary bases; the former comes in far above the latter, or at a long period subsequent to the time when deposits began to be formed.

"6. The Taconic system carries us back many stages farther in time, when life gave vitality to its waters, than the Silurian. It represents a period vastly longer, though it may occupy a less superficial area." *

In Chapters X., XI., and XII. of his "Geological Report of the Midland Counties of North Carolina," (Raleigh, 1856, 8vo,) Dr. Em-

* American Geology, Part II. The Taconic System, p. 122.

mons gives a description of the Taconic system in that State. He points out the existence of fossil corals in the lower Taconic series near Troy, in Montgomery County, and describes and figures them, pages 62 and 63, under the name of *Paleotrochis major* and *P. minor.* There are some doubts as to their organic character, and it is possible that like *Eozoön* they belong to the mineral kingdom.

1859–60. — In his "Manual of Geology," first published in 1859, and a second edition in 1860, (New York, 8vo,) Prof. Emmons describes the Taconic system in Chapter XI. pp. 81 to 89. "This system is subdivided into a *Lower* and *Upper;* the first consists of a conglomerate at the base, succeeded by silicious talcose beds of considerable thickness, in which there are frequently pebbles; next above, are three thick beds of sandstone, separated by talcose slates; these are succeeded by the Stockbridge limestone. This is the marble of Berkshire County, Massachusetts, which extends from the State of Vermont to Georgia. The Stockbridge limestone is succeeded by a mass of slate of great thickness, the upper part of which is suitable for roofing. The greatest thickness of the Lower Taconic rocks is about 5,000 feet. . . . . *Upper Taconic rock* consist of numerous beds of slate alternating with shales, thin-bedded sandstone, some of which are coarse and brecciated, thin-bedded bluish limestone, more or less cherty and checked with seams of white calcareous spar, and red, brown, and purple roofing-slates. . . . . According to Barrande, the *Paradoxides* and *Olenus* belong to his primordial zone, or are Sub-silurian in Bohemia. In this respect our *Paradoxides* are also Sub-silurian; and *hence it has been shown that the primordial zone in Bohemia is in co-ordination with the upper series of the Taconic rocks.*" A most important remark, at a time (1859) when every geologist and palæontologist in America except Colonel Jewett and Billings, were against the existence of the Primordial zone in the Taconic system.

Finally, Emmons, in a note at the end of the second edition, 1860, of his Manual of Geology, page 280, says: "The slates or shales referred to (in the Regent's Report of New York for 1859), in Northern Vermont, as constituting a new series above the so-called Hudson River group, instead of ranking thus high in the geological scale, are really sub-silurian, as is fully proved by the overlying calciferous (red sand-rock) sandstone. . . . . We now know the following Trilobites, all of which belong to a slate beneath the calciferous," (Emmons called the red sand-rock of Vermont, which is since proved to be identical with the Potsdam sandstone, *Calciferous sandstone,*) "viz.: *Atops punctatus, Eliptocephalus* (*Paradoxides*) *asaphoides, Paradoxides Thompsoni,*

Par. Vermonti, Par. macrocephalus, Par. (*Pagura*) *quadrispinosus,* and *Microdiscus quadricostatus.*"

This finishes the list of documents published by Dr. Emmons. In September, 1860, he went to North Carolina as State Geologist, and continued within the enemy's lines during the civil war until he died, in 1863, at his plantation in Brunswick County, on the 1st of October. Notwithstanding the difficulty of his position, he received the first memoir published in his favor by Barrande and Marcou at the end of December, 1860, and the following extracts are from his last letters.

We must remember that a powerful, systematic opposition, verging on persecution, had been at work from the beginning against the Taconic system and its author. This is necessary in order to follow clearly the progress and development of the Taconic system question. Its adversaries pretended that the strata in the northern part of New York State, placed beneath the Potsdam sandstone by Emmons, were the beds of *Lorrain Shales*, above the " Utica Slate," these being called *Hudson River group* for the eastern region of the State; that farther east these beds of the Hudson River group were followed in concordant superposition by *metamorphic* rocks, which were, according to them, the "Upper Silurian" and even "Devonian." In a word, the Potsdam sandstone was the base of the sedimentary rocks, the most ancient group of all, resting directly upon the gneiss and granite; and even sometimes, as in the Highlands, the Potsdam sandstone was altered and " becoming gneissoid and granitic."

The positions were well taken. On the one side, Dr. Emmons described strata thirty thousand feet in thickness as a special system of rocks having a well-defined stratigraphy, its own lithology, and containing its own fossil organized remains, constituting the most ancient and the most important system in the stratigraphic series. On the other hand, his adversaries denied all this *in toto*, using the very elastic word *metamorphism* to explain everything.

1859–60. — " The Twelfth Annual Report of the Regents . . . . of the State Cabinet of Natural History " of New York, dated March 15, 1859, Albany, contains (p. 59) a notice under the title of " Trilobites of the Shales of the Hudson River Group."

There are only three fragments of Trilobites described by Prof. James Hall, under the names of *Olenus Thompsoni*, *Olenus Vermontana*, and *Peltura* (*Olenus*) *Holopyga*.

The description of these fossils collected from the schists " in the town of Georgia," and presented as coming from the shales of the *Hudson River group* of Vermont, ends with the following note: " In

addition to the evidence heretofore possessed regarding the position of the shales containing the Trilobites, I have the testimony of Sir W. E. Logan that the shales of this locality are in the *upper part of the Hudson River group*, or forming a part of a series of strata which he is inclined to rank as a distinct group *above* the Hudson River proper. It would be quite superfluous for me to add one word in support of the opinion of the most able stratigraphical geologist of the American continent."

This little notice had the privilege of drawing the attention of Joachim Barrande, "the inventor of the primordial fauna," as he was happily styled by D'Omalius d'Halloy, and here follow, in the order of their dates, the correspondence and publications brought about by the intervention of Barrande.*

"PARIS, 28 Mai, 1860.

"MON CHER MONSIEUR MARCOU: —

". . . . Si vous voyez le Prof. W. B. Rogers, je vous prie de lui dire, que je suis très reconnaissant des trois belles photographies de *Paradoxides Harlani* Green, qu'il a eu la bonté de m'envoyer. Elles ont beaucoup intéressé notre société géologique à laquelle je les ai montrées, en constatant que cette espèce est identique avec *Parad. spinosus* de Bohême. C'est un fait très important, et qui doit avoir d'heureux résultats, pour établir les relations d'âge entre les formations les plus anciennes des deux continents.

"Par occasion, je désirerais beaucoup savoir par le Prof. Hitchcock, géologue de Vermont ou par tout autre savant qui aurait étudié le terrain: —

"1°. Quels sont les fossiles qui se trouvent dans les mêmes couches qui ont fourni les trois trilobites récemment d'écrits par J. Hall dans le *12th Annual Report of the Regents of the University of New York*, p. 59, sous les noms de *Olenus Thompsoni*, *Ol. Vermontana*, et *Peltura* (*Olenus*) *Holopyga*.

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* Colonel E. Jewett, Curator of the State Cabinet of Natural History of New York at Albany, "during the numerous excursions he had made over the disputed territory, had arrived at the conclusion, from his own observations, that Dr. Emmons was, upon the whole, correct in his views," and Billings, "on the 25th of April, 1860, ... sent a copy of Prof. Hall's pamphlet, containing the figures and descriptions (of the three Vermont Trilobites) to Barrande, then in Paris," and said, "I referred him to these three trilobites, as an example of a group of primordial fossils, in rocks which were considered by American geologists to be of the age of the Hudson River formation." — Remarks on the Taconic Controversy, by E. Billings, in "The Canadian Naturalist," New Series, vol. vi. pp. 315 and 317 (Montreal, 1872).

"Ces trois fossiles auraient été trouvés dans les schistes de la ville de Georgia admis comme recouvraut le groupe de Hudson River; d'après l'autorité de Sir W. Logan, invoquée par J. Hall.

"2°. Sur quelle sorte de preuve repose la détermination de cet horizon?

"Le terrain de ce pays est-il tellement simple et clair dans sa constitution stratigraphique, qu'on ne puisse avoir aucun doute sur cette détermination? ou bien, y a-t'il des accidents locaux qui pourraient faire hésiter sur le véritable horizon auquel on doit rapporter les schistes de Georgia?

"Le fait est que ces trois *Olenus* seraient fort surprenants dans une formation au dessus de 'Hudson River group.'

"D'un autres côté nous avons deux exemples assez remarquables des rectifications que la paléontologie, bien entendue, peut faire dans les travaux purement stratigraphiques. D'abord au sujet des collines de Malvern en Angleterre, qui nous offre réellement la faune primordiale au lieu de celle de Caradoc que le *Geological Survey* y avait déterminée. En second lieu au sujet de la chaine Cantabrique où la même faune primordiale vient d'être reconnue en contact immédiat avec la faune dévonienne avec laquelle elle avoit été confondue par tous les géologues. . . . .

"J. Barrande."

"Paris, 14 Août, 1860.

"Mon cher M. Marcou:—

"Votre aimable lettre du 30 Juin dernier m'est parvenue le 17 Juillet, lorsque j'avais déjà écrit la lettre à M. Bronn, dont la copie est ci-jointe. Vous jugerez aisément, que la question est importante et fort intéressante, lors même qu'elle ne serait soulevée qu'à l'occasion des trois *Olenus* de Georgia. Mais elle prend subitement une grande extension par suite d'une lettre de M. Billings que je viens de recevoir. M. Billings m'annonce qu'il vient de recueillir, aux environs de Quebec, dans des schistes et calcaires considérés comme formant la prolongation de ceux de Vermont en question, une suite de près de 100 espèces, presque toutes nouvelles. Dans ce nombre, 26 qui provienment d'un calcaire *blanc*, lui semblent être de véritables représentant de la faune primordiale; et il cite parmi elles des *Conocephalites*, *Arionellus*, *Dikelocephalus*, etc., c'est-à-dire des formes qui sont en effet très caractéristiques de cette faune. Dans un autre calcaire, qui est *gris*, il trouve 39 espèces, toutes différentes des premières citées, et représentant, au contraire, les types les plus prononcés de la faune

seconde. Enfin les schistes noires lui fournissent des *Graptolites*, des *Lingules*, etc., c'est-à-dire des formes dont la première vue ne peut pas déterminer l'horizon, parcequ'elles se trouvent sur divers horizons siluriens.

"Quant à l'ordre de succession des roches diverses, renfermant ces trois groupes différents de fossiles, M. Billings ne s'explique pas, ou ne se prononce pas encore, car le fait est tout récent et doit être à l'étude.

"Mais, en attendant que les relations stratigraphiques très obscures, soient débrouillées, et sans engager en aucune façon M. Billings, qui doit conserver toute l'indépendance de son opinion, je crois pouvoir vous exprimer ma manière de voir, toute personelle, et dont je dois en ce moment prendre seul la responsibilité. Je pense donc, que cette région des schistes et calcaires de Vermont, du *Taconic system*, en d'autres termes, reproduira en Amérique ce qui a eu lieu en Angleterre pour les collines de Malvern; c'est-à-dire que la faune primordiale, après y avoir été méconnue, y reprendra ses droits et sa place, usurpée par la faune seconde.

"Vous voyez que c'est une grande et belle question, dont la solution finale complétera les importantes harmonies, qui existent déja entre la série des faunes paléozoiques d'Amérique et celle des faunes contemporaines d'Europes, en laissant à chacune l'empreinte particulière à son continent.

"Je conçois très bien d'après les positions antérieurement prises par nos savants confrères américains, au sujet du *Taconic system*, que la solution finale dont je parle ne sera pas obtenue sans contestations et peut-être sans quelques froissements d'amour propre, car il faudra abandonner quelques opinions qui paraissent être dominantes. Mais l'expérience m'a enseigné qu'en pareil cas, ce sont toujours les esprits les plus élevés qui s'ouvrent les premiers à la lumière, et qui se mettent en tête du mouvement de réforme.

"Ainsi lorsque en 1850 j'ai reconnu la faune primordiale dans les collines de Malvern, où l'on n'avoit vu que la faune seconde, Sir Henri de la Bèche et Sir Roderick Murchison ont les premiers adopté mes vues, auxquelles se sont ralliés peu à peu les autres géologues officiels. Edouard Forbes n'a pas hésité à se ranger publiquement à mon opinion, dès 1853, lorsque d'autres hésitaient encore, dans le *Geological Survey*. Aujourd'hui il n'y a plus aucun opposant à ce sujet.

"Je me figure qu'il en sera à peu près de même en Amérique, et que d'ici à peu d'années l'opinion des savants aura subi une profonde modification, en ce qui touche cette question.

"Si le Dr. Emmons fait encore de la géologie, c'est pour lui une belle occasion pour reproduire ses anciennes observations et ses idées, avec plus de succès qu'en 1844. Le connaissez vous? Pourriez-vous l'instruire de ce qui se passe? en lui communiquant ma lettre à M. Bronn.

"Comme j'ai envoyé copie de cette lettre à Sir W. E. Logan, en le priant de la transmettre à Mr. J. Hall, vous sentez que la communication à d'autres personnes est maintenant bien permise, et par conséquent vous pouvez faire de cette lettre l'usage que vous jugerez à propos, et même la *publier* s'il y a lieu.

"Dans tous les cas, je vous prie de la montrer à M. Agassiz. Par la même occasion, vous pouvez lui dire qu'il peut compter sur la parole que je lui ai donnée, au sujet de mes *duplicata*, dont j'ai déjà préparé une partie à son intention. Mais, au milieu de mes occupations et affaires, il m'est difficile de consacrer à ce travail minutieux tout le temps qu'il exige pour être fait convenablement. . . .

"J. Barrande."

Part of this letter and one paragraph of the letter of May 28 were published in the Proceedings of the Boston Society of Natural History, Vol. VII. pp. 369 to 375, December, 1860. The letter to Prof. Bronn of Heidelberg, referred to, was also translated by Mrs. Marcou, and published in a communication made before the Boston Natural History Society, October 17, 1860, under the title, "On the Primordial Fauna and the Taconic System, by Joachim Barrande; with additional Notes, by Jules Marcou." (Vol. VII. p. 371.) It was also published in German and in French, at Stuttgart and Paris.

"Albany, September 1, 1860.

"To Prof. J. Marcou.

"My dear Friend, ... I shall, and do now hope that I may enlist you in the controversy respecting *the Taconic rocks*, and I want exceedingly to show you places of importance and of great interest, and I know what your opinion will be beforehand, though now you may, and probably do, entertain views directly contrary to my own. I have forborne to bring the question relative to the existence of the Taconic system before you, for it was not the time; but as you must now be an American geologist, I hope all American questions will be entertained and investigated by you. Yet it is not an American question exclusively, for the upper part of the Taconic is equivalent to Barrande's *Primordial Group*. . . .

"E. Emmons."

"MONTREAL, October 30, 1860.

"To M. JULES MARCOU.

"MY DEAR SIR, ... I have read your Geological History (in 'Geology of North America,' p. 99, Chapter IX., 4to, Zurich, 1858) with great pleasure. That work contains many views which are precisely in accordance with those which I have long entertained, but never saw in print before. Professor Dawson informs me that you are about to investigate the Primordial Zone of North America, or the Taconic system of Emmons. I am glad that you have taken up this subject. . . . . I have been attached to the Geological Survey of Canada only four years, and the Taconic question, so far as it has been investigated here, was settled long before I ever saw either Professor Hall or Sir W. E. Logan. Hall, although not on the Survey, was the palæontological adviser, and he decided that the Quebec rocks were Hudson River, because they contained Graptolites. Taking these rocks as a starting point, Sir William, with immense labor, traced out the geographical distribution and physical succession of all the others in the disturbed region of Canada East. You will see that, if there has been any mistake made, it originated in Hall's determination of the fossils of the Point Lévis or Quebec Graptolites. Hall's mistake, I think, is partly due to his ignorance of the geology of Europe. He has always been of opinion that in Europe Barrande's Primordial Zone overlies the Lower Silurian. You will see by reference to Foster and Whitney's 'Report on Lake Superior,' page 318, in the comparative table which he gives on the European and American formations, that he places the 'alum schists and argillaceous schists of Northern Europe with *Graptolites*, *Olenus*, *Ampyx*, etc.,' above the 'Orthoceratite limestone.' Now, it is well known that the 'alum slates' of Sweden constitute the *Primordial Zone*, or Angelin's *Regiones* A, B, and also that they underlie the 'Orthoceratite limestone.'

"Emmons is the man who actually made the discovery of the Primordial Zone on this continent, and who is entitled to the credit; and when we consider that he has stood alone against all the leading geologists of America for more than twenty years, it would be hard if his . . . . opponent were to come in and share the honor with him.

"I made the above statements upon the supposition that it will be proved by physical geology that the 'Champlain series,' from the Potsdam upwards, do overlie the Taconic rocks. I have examined the fossils only, and such as I have seen appear to me to represent in part the fauna of Angelin's *Regio* B C, and in part the Primordial

Zone. I have become of late very deeply interested in this question, and would like to see it settled; but I do not, owing to my peculiar relations with others, desire to be recognized publicly in the matter. It is on account of my interest in the question, and because I like your writings, that I take the liberty of communicating thus freely with you, although you are a stranger to me, and may feel surprised that I should take such freedom.

"Yours, with the greatest respect,

"E. BILLINGS."

"RALEIGH, N. C., November 6, 1860.

"PROF. JULES MARCOU.

"MY DEAR SIR, ... But of all the erroneous opinions ever published in this country, are those adverse to the *Taconic system*, a system which stands out as boldly in our system of rocks as the Carboniferous. . . . .

"E. EMMONS."

"RALEIGH, November 19, 1860.

"PROF. J. MARCOU.

"MY DEAR SIR, ... I am right in the Taconic system! and of [*sic*] that, though it may not be so clear in the book [referring to his Manual of Geology], is clear as daylight in the field. But (*inter nos*) I do not think Barrande goes far enough; and I do not think him right in maintaining that his Primordial group is a part or parcel of the Silurian. And if you have taken that view you will have to back out, for the Lower Silurian is strictly unconformable to every part of my Taconic series; and this series is *sui generis*, one *geologically*, *stratigraphically*, and *palæontologically*, with a host of other long words, separate and distinct from Silurian.

"E. EMMONS."

"RALEIGH, November 20, 1860.

"PROF. JULES MARCOU.

"MY DEAR SIR, ... I sent, three or four weeks ago, all my publications to Barrande, who has written me, though they had not reached him. Perhaps yesterday I did Barrande injustice, if a person in my position and acquirements can do so. On reading his papers, I found that, after all, his Primordial group is *only Lower Silurian.* I conceive we have exactly his *Primordial group* in the band of slates containing the *Paradoxides*. But this band is only a very narrow belt of beds.

"I need not dwell on this point. We can discuss this question when face to face. Only my remarks are not intended to convey the slightest disparagement of his discoveries in that particular, and I believe, if he was here, he would no longer maintain the doctrine that this group is Silurian. I shall wait with anxiety the reception of your promised paper. You have already, as Colonel Jewett tells me, stirred up my opponents, one of which took the Colonel to task a few days ago for his belief in the 'Emmonsian myth.'

"E. EMMONS."

The promised paper spoken of in this last letter of Emmons was my communication to the Boston Natural History Society, 17th October, Vol. VII. of the Proceedings, pp. 357 and 369, under the title of "On the Primordial Fauna and the Taconic System, by Joachim Barrande; with additional Notes by Jules Marcou." A very short *résumé* only appeared in the proceedings of the meeting of October 17. However, the priority of the discoveries of Emmons was stated; also, that "the Taconic system is equivalent to the Primordial fauna of Barrande"; and "Mr. Marcou considers this [the Potsdam sandstone] not the first fossiliferous stratum, but the last of a series containing the Primordial fauna." Finally, the memoir was accepted for publication, and it was placed among the proceedings of the next meeting, November 7.

These statements were the starting-point, and the pivot on which the evolution of the views regarding the Hudson River group as the last and uppermost division of the second fauna revolved; and the Taconic system was again brought forward.

Here follow, successively, and in their order of dates, the most important letters and notes.

"MONTREAL, December 21, 1860.

"M. JULES MARCOU.

"MY DEAR SIR, — I have seen your paper in the Proceedings of the Boston Natural History Society.* I think you are right when you say that Emmons should have included the Potsdam in the Taconic. . . . . I very much wish this question [of the Taconic and Primordial zone] was settled, but I think it will be two or three years before any conclusions that will satisfy all parties will be arrived at.

* The signature of the sheet of the Proceedings is 24 December, 1860. So copy or copies were sent, without my knowledge, to Montreal, as early at least as the 19th of December.

"I beg to state that the limestone at the top of the fall at Montmorency is Trenton limestone, and full of fossils. I have collected a good many there myself. I did not examine the rocks at the foot of the fall, as I had no idea when I was there that any question as to its age would ever arise.

"E. BILLINGS."

"RALEIGH, December 28 or 29, 1860.
[Postal mark, December 29.]

"PROF. J. MARCOU.

"MY DEAR SIR, — I thank you for your pamphlets, and am exceedingly gratified with the view you have taken of the question. It is presented in an unanswerable form. I have dwelt more upon the stratigraphical relations of the two systems; because, to ordinary readers, that is perfectly obvious. I insisted, however, upon the palæontological view, the palæontological evidence; and said often, that, if this was rejected, then ought all of this kind of evidence to be rejected elsewhere. Mr. J. Hall insisted upon the identity of the *Atops* and *Triarthrus;* notwithstanding the decision years ago by a committee of the American Association, of whom [*sic*] Conrad was a member, was against Hall.

"I made and published with my Report while in the survey of New York a modified map of the State, which showed the extent of the Taconic rocks in New York. The three thousand copies were stolen or destroyed by persons unknown, so that they were never issued with the proper volume. The rocks illustrating the Taconic system in the State Cabinet were all taken out by order. . . . . My existence as one of the State geologists was ignored at the last meeting of the American Association at Albany. In fine, the persecution I suffered for opinion has been rarely equalled. . . . . The editor of the American Journal of Science refused to publish my remarks upon Logan's Report, when he announced his Huronian system; though they were courteous in the extreme. I claimed that the *Huronian* was only the *Taconic system*. . . . . Are you aware that most, if not all, of those beautiful Graptolites Mr. Hall refers to the Hudson River group belong to the Taconic system? Nothing of the kind occurs in the Lorrain slates, or the shales about Rome, where the rocks are undisturbed; there are probably two species in the Trenton and the slates above. No more.

"I shall be very much obliged to you for six more copies of your paper.

"E. EMMONS.

"P. S. As it regards the Potsdam sandstone I think you right, so far as Owen's discoveries are concerned. It is a point I have not thought of, and is new to me. The suggestion is a good one, and must be met."

"RALEIGH, December 30, 1860.

"PROF. J. MARCOU.

"MY DEAR SIR, — I wish, if not inconvenient, you would send three or four copies of your pamphlet to Colonel E. Jewett, Curator of the State Cabinet of Natural History, Albany. He is now one of the strongest friends I have, and will do much to disseminate the truth. . . . . I have no doubt that, for fossils, the Taconic is the best field for work which remains, though it may not prove to be productive in numbers.

"E. EMMONS."

"RALEIGH, January 23, 1861.

"PROF. J. MARCOU.

"MY DEAR SIR, — I am under the highest obligations to you for the decided part you have taken in the question respecting the Taconic system. Your example and decision, and judicious statements, have effected a revolution in opinion quite remarkable. I should not forget Mr. Billings; for, placed as he was, he must have run great risks in the course he took; but no man is good for anything unless *he dare express an opinion* when he has formed one. . . . . It was ten years ago, I think, when I claimed Logan's Huronian system as nothing more than the Taconic. . . . .

"It is really a matter for wonder that Sir Wm. Logan has conceded as much as he has. I am told he has not done the thing *very* gracefully. But the case was one that there was no way to get around it, nor over it, nor through it; sooner or later, the acknowledgment must be made, and the sooner was the wise course. I have not yet seen what he answered to Barrande.

"Colonel Jewett is a capital man. He is not afraid to speak what he thinks.

"When once the Primordial group is recognized, the rest follows necessarily, unless an older system is called up and a new name given.*

* Dr. Emmons has evidently no idea that a part of the Primordial zone will be called "Quebec group," and placed above the Potsdam sandstone, and as a substitute to the Calciferous, the Chazy, and the Trenton groups. An expedient so contrary to what exists in the field never came into his mind.

The idea of Prof. Hitchcock that the Berkshire marbles are *Devonian* is a great way from the truth; because, in the range of mountains between New York and Massachusetts, this limestone lies below the slates which run up into those containing the primordial trilobites.

"The acknowledgment of the *Primordial of Barrande in this country* is really one of the finest and best facts in geology, making a *co-ordination of American and European rocks so complete and harmonious;* I think of nothing I have said or done in this matter; I look upon the harmony of the systems; they are truly worth dwelling upon; and a great deal more is yet to come out.

"I want much to see you when I get to Albany in the spring, to look over with me my fossils from the Trias and Dyas. — By the way, this puts me in mind of the *Dyas* controversy with Murchison; and I think you have got the better of the old Dictator; and the Dyas must stand and take the place of Permian.

"E. Emmons."

"Raleigh, January 28, 1861.

"Prof. J. Marcou.

"My dear Sir, — You will excuse me for addressing you at this time, or again, inasmuch as my letters, I fear, may get to be troublesome. But I wish to say two or three things about your proposition to place the Potsdam sandstone at the top of Barrande's Primordial group or my Taconic system. Let me declare, once for all, that I have not the slightest objections to your view; as if when established it would diminish aught of the importance of my views; but simply to present something for your consideration before the Potsdam rock, as I established it in 1836–37, is abandoned as the base of the Silurian system.

"In St. Lawrence and Jefferson Counties, where first observed, it is underlaid by beds of *coarse granitic conglomerate,* and then graduating into a fine even-grained sandstone, and then the sandstone graduating again into the Calciferous sandstone above, the latter of which is perfectly conformable,* so that there is no line really of demarcation between the Potsdam and the Calciferous. Now in the region I have named I see no possibility of excluding the Potsdam from the Silurian system, and there are no fossils except a single *Lingula*

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* It is a mistake. I have observed since at Chazy and Potsdam a discordance of stratification of 15° between the Potsdam sandstone and the Calciferous sandrock. — J. M.

scarcely differing from the one in the Calciferous.* So much for the St. Lawrence region.

"But now as to Iowa and the West, I understand Owen to say, that far below what he would call the Potsdam proper, there are beds with Primordial fossils (he does not use the word, but we may). Here, then, we have got down to another series, which no doubt appears to be conformable with the Silurian, but with peculiar fossils and in abundance. These no doubt should be regarded as the upper part of the Primordial series, and it may be contain sandstones. I have not Owen's book to refer to. Again, not having seen these beds, I have no satisfactory knowledge how they lie; but those sandstones may be placed as you suggest. And I go further, and say, if you believe you can make out a good case with the Potsdam anywhere, I never shall object, for I have no wants except truth.

"But the break, or the heavy conglomerate at the base of the Potsdam in St. Lawrence County, seems to me to favor the position I took, that the sandstone and conglomerate beds are at the base of the Silurian. I merely suggest these facts for your consideration.

"In conclusion, allow me once more to thank you for all you have done in American geology, and especially for the benefit you have been to your servant,

"E. Emmons."

This letter is the last I received from Emmons. After the breaking out of the civil war, I was unable to send either the memoir of Barrande, "Documents anciens et nouveaux sur la Faune Primordiale et le Système Taconique en Amérique," or my observations and pamphlets of 1861 and 1862, entitled, "The Taconic and Lower Silurian Rocks of Vermont and Canada" (Proceedings Bost. Soc. Nat. Hist., Nov. 6, 1861), and "Letter to M. Joachim Barrande on the Taconic Rocks of Vermont and Canada" (Cambridge, 1862). The impossibility of reaching him left Dr. Emmons partly in ignorance of the efforts made in favor of his "Taconic system."

These last letters, the two dated in January, 1861, are given to show his opinions at the moment of the change made in the official classification of the geological survey of Canada. They were written in ignorance of the printed letter of Logan to Barrande, and it is doubtful if Dr. Emmons ever saw it.

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* Several fossils have been found since in the Potsdam sandstone near Keeseville, besides the *Lingula* (*Obolella*) *prima*, such as *Lingulepsis minima*, *Conocephalites minutus* and *C. Verrucosus* Whitf., entirely Primordial fossils.

The letter of Billings, 21 December, shows an acquaintance with the memoir containing extracts from three letters of Barrande; the official date of this memoir is 24 December, 1860, printed at the foot of the page, and its having been sent to Montreal before its issue at Boston, and before I had seen it even, is a sufficient proof of the interest excited by it; it was in part reprinted immediately in several scientific journals.

1861. — Logan could hardly delay any longer his answer to Barrande's letter of 1860, containing a copy of the letter to Prof. Bronn. The publication of this letter in English rendered it necessary for him to make a decision. After great hesitation he decided to write a printed letter, entitled, "Remarks on the Fauna of the Quebec Group of Rocks, and the Primordial Zone of Canada, addressed to M. Joachim Barrande." 31 December, 1860, is the date of the letter; the date of the impression is 3 January, 1861, and it was distributed and sent from Montreal on the 12th of January. This document of five pages is the letter of a diplomatist rather than of a geologist.

The explanation of the stratigraphy of Point Lévis is unintelligible; so much so, that some months later he was unable to explain it to me on the map made by himself of Point Lévis; and that on the ground, after two successive studies made in 1861–62, I was unable to make this explanation agree with what exists at Point Lévis.

The principal concession of his letter is the existence of what he erroneously calls the "Quebec group" (it is in reality the "Point Lévis group"), of a thickness of perhaps some 5,000 or 7,000 feet, which he regards as equivalent to, and on the horizon of, the two divisions of Chazy limestone and Calciferous sandrock with points of "overturned Trenton" from time to time framed therein, in Vermont, but not in Canada. Further, he thinks the "*Olenus* shales of Georgia" are interposed in the strata of the Quebec group, and that the whole rests upon the "Potsdam formation," which, according to him, forms the "New Primordial zone in Canada." A paragraph is given to Lake Superior, where he looks upon the sandstone as Chazy, Calciferous, and Potsdam, or the equivalent of his Quebec group; and the rocks containing copper as belonging to his Huronian system.

Finally, he admits that Prof. Emmons was certainly right to maintain that the rocks in Vermont are older than the Birdseye formation; and that Billings regards the trilobites of the Quebec group as indicating that this group is nearly at the base of the second fauna. The last phrase declares Georgia to be a constituent part of the Primordial zone, contrary to what he had said a few paragraphs back.

This letter does not allude to the memoir published a fortnight previously at Boston, which he had received, as appears from the letter of Billings.

Three communications were made by M. Barrande to the Geological Society of France at the meetings of the 5th and 19th of November, 1860, and the 4th of February, 1861, which appeared under one title, as "Documents anciens et nouveaux sur la Faune Primordiale et le Système Taconique en Amérique." This memoir, so remarkable for its clearness, impartiality, and the opinions it contains, is an admirable justification of the "Taconic system." We can only regret that Emmons only knew of its existence, without being able to see it.

Several unpublished letters of Barrande, of January, 1861, and later, are given as important in showing the progress accomplished by his intervention.

From far distant Bohemia, where he had studied with the greatest care, first the stratigraphy and then the palæontology of a very small geologic basin in the centre of Europe, Barrande recognizes that Emmons is right in placing the strata of the eastern part of Lake Champlain below those of the other side of the lake on the western shore in the State of New York; that he is correct in placing below the second fauna a Primordial fauna contained in beds that constitute the Paleozoic base, and a wholly new system justly called by him the "Taconic system"; that the opposition to these views for twenty years past is not only unjust, but erroneous, and that his adversaries have only to change their base and adopt more correct ideas. At so great a distance, he cannot enter into details; these he leaves for those on the ground, who study the stratigraphy of these regions, contenting himself with having brought forward the "Taconic system," and shown all its value and importance.

"Paris, 20 Janvier, 1861.

"Jules Marcou, Esq.

"Mon cher Confrère,—J'ai successivement reçu vos deux lettres du 16 et 24 Décembre avec vos deux envois de brochures, comprenant 20 exemplaires, outre la première épreuve, et la note de notre ami M. Agassiz sur l'origine des espèces.

"Votre long silence ne m'a pas étonné et je l'avais même interprété assez justement, car je m'étais figuré que, ne pouvant obtenir à Boston, des documents assez positifs sur le terrain Taconique, vous aviez pris le parti d'aller en personne sur les lieux. Je supposais que vos explorations avaient exigé tout ce temps et j'attendais patiemment vos

résultats. Je ne m'étais pas trompé en principe, puisque votre lettre du 16 Décembre me fait part de vos projets d'excursions et des circonstances contraires, qui les ont fait ajourner à l'année prochaine. Je ne puis que louer vos résolutions à ce sujet et j'espère que vous ne quitterez pas la contrée Taconique sans avoir résolu les divers problèmes géologiques auxquels elle a donné lieu. Vous avez toutes les qualités nécessaires pour ces explorations, qui exigent l'intelligence, l'indépendance, et un véritable dévouement à la science.

"Je vois par vos lettres que vous avez pris la bonne méthode dans les discussions qui ont eu lieu aux réunions de votre Société d'Histoire Naturelle [Boston Soc. Nat. Hist.]. Il ne s'agit pas de théories, qui ne mènent à rien, mais bien de faits positifs sur lesquels il parait que les explorateurs du pays sont encore un peu en arrière puisqu'aucun d'eux ne présente des sections dont il puisse garantir l'exactitude.

"Dans ma position lointaine, je distingue deux questions très différentes. La question stratigraphique qui est jusqu'ici la moins claire, est entièrement hors de ma portée. La question paléontologique est beaucoup plus simple, et bien que les éléments de la faune Taconique soient encore très incomplets, quelques uns d'entre eux sont assez clairs pour qu'un observateur même éloigné soit frappé par les analogies qu'ils présentent avec la faune Primordiale. Je veux parler surtout des trois *Olenus* de Georgia et de quelques fragments publiés par le Dr. Emmons. M. Angelin qui a passé ici quelques mois, et à qui j'ai montré tous ces documents, partage entièrement mon opinion à cet égard et m'a autorisé à publier son assentiment.

"Remarquez bien que je n'ai pas déterminé le genre de ces Trilobites, par la simple raison qu'ils sont encore incomplets. On pourra même leur donner tous les noms nouveaux qu'on voudra, ils n'en resteront pas moins des formes d'apparence primordiale.

"Les livres du Dr. Emmons ne circulent pas sur notre vieux continent, et s'il n'avait pas eu l'aimable attention de m'en envoyer quelques uns, il m'eût été impossible d'exposer ses idées, que je ne connaissais guère, d'après les ouvrages qui sont entre mes mains.

"Je vous suis très reconnaissant des traductions aussi élégantes qu'exactes de mes diverses lettres. Vous avez bien exposé la question et vous avez fait une intéressante excursion dans le Canada (1849) où la question Taconique se présente sous des apparences aussi compliquées que dans la région typique. Il faut vraiment que vos notes de voyage soient bien fournies et votre mémoire bien sûre, pour que vous ayez pu vous retrouver ainsi sur les bords du St. Laurent.

"Une lettre du Prof. Phillips (Oxford) que je reçois, me porte à

croire qu'il a déjà lu votre publication, car il pense comme nous sur le système Taconique.

"Vous me dites que notre ami M. Agassiz et Mr. Albert Ordway, après avoir comparé douze exemplaires de *Paradoxides Harlani* avec *Par. spinosus* observent entre eux des différences assez marquées et constantes, pour croire que ce sont deux espèces distinctes. Je trouve ce jugement très convenable, car je sais que M. Agassiz a toujours maintenu l'espèce dans des limites très étroites. Quant à moi au contraire, je prends des limites beaucoup plus larges et j'y suis forcé sous peine d'être entraîné à distinguer six ou huit mille espèces dans mon petit bassin de Bohême, au lieu de deux mille trois cents que je suppose exister. J'ai par exemple telle espèce d'Orthocère, qui pourrait bien en fournir une dizaine à divers paléontologues. Mais plus j'étudie, plus je vois la nécessité de prendre mon parti en pareille matière, sans quoi la science des fossiles paléozoïques deviendrait un dédale inextricable.

"Je vous dirai qu'à mon point de vue personnel, le groupement des formations, sous des noms de systêmes ou autres, me paraît d'une importance secondaire et transitoire. J'admets, donc volontiers des grandes divisions qui me semblent suffire pour le moment, mais je crois que peu à peu toutes ces classifications seront remaniées et transformées par les progrès de la science. La chose la plus importante doit être de bien étudier dans chaque pays la succession des faunes et de bien définir les éléments dont elles se composent. Nous ne savons pas bien encore, jusqu'à quel point chacune d'elles pourra être définie entre des limites verticales fixes. C'est là justement ce qui résultera de nos études comparées sur les deux continents. Pour moi, je me borne aux trois faunes siluriennes de la Bohême, parce que le sujet est déjà assez vaste pour absorber tout mon temps.

"Il paraît que les indications des étages par des lettres vous semblent difficiles à retenir. Cette méthode a cependant un grand avantage, c'est d'indiquer immédiatement l'ordre de succession et la superposition. C'est pour cela que je l'ai adoptée. Du reste, pour fixer mieux les idées, j'accompagne ordinairement, dans le texte, chaque lettre par une autre définition. Ainsi, je dis par exemple : *Etage des quartzites D.* — *Etage calcaire inférieur E,* de sorte que le lecteur n'est pas en face d'un signe abstrait. Mon terrain ne se prête pas à l'emploie des noms de localités ; et si j'avais voulu par exemple dire : — *Calcaire de Konieprus,* il y aurait eu un malentendu continuel, parce que cette localité présente deux étages de calcaires, différents d'âge, et tous les deux bien développés. Il en est de même dans la plupart de mes

localités importantes. J'ai donc dû éviter d'employer leurs noms. Lorsque je lis les ouvrages américains sur le terrain paléozoïque, cette longue série de noms de localités, qui vous paraît si claire et si simple, m'embarrasse toujours, et je me vois obligé de consulter de temps en temps le tableau de superposition, pour bien fixer mes idées. Je crois donc que chaque système de notation a ses avantages et inconvénients et je trouve tout naturel que chacun préfère le système auquel il est le plus habitué.

"J. BARRANDE.

"P. S. 5 Février. — Cette lettre ayant été interrompue à plusieurs reprises, représente un couple de semaines. Je suis heureux de ne l'avoir pas expédié plutôt, afin de pouvoir vous annoncer que je viens de recevoir la Notice de Sir W. E. Logan, intitulée, *Remarks on the Fauna of the Quebec Group of Rocks, and the Primordial Zone of Canada*, etc. Le Prof. Emmons doit être satisfait du paragraphe qui le concerne. Il me tardera de savoir comment cette déclaration de M. Logan sera acceptée à Albany. Je remarque que le nom du Prof. J. Hall y est à peine mentionné.

"Il est clair que les environs de Québec présentent des difficultés stratigraphiques considérables, pour reconnaître l'ordre de dépôt des couches indiquées par A_1 — A_2, etc., B_1 — B_2, etc. Mais cette classification n'est que secondaire."

"PARIS, 7 Février, 1861.

"MON CHER MONSIEUR MARCOU: —

"Je viens de recevoir votre lettre du 21 Janvier. Je vois que les *Remarks on the Fauna of the Quebec Group, etc., addressed to Mr. Joachim Barrande,* de Sir W. E. Logan, ont produit sur vous les mêmes impressions que sur moi. Puisqu'il a si galamment pris sa résolution, vous dites très bien qu'il serait inopportun de s'appesantir sur les questions accessoires, qui demandent encore à être éclaircies. Chacun apportant dans ces débats l'amour pour la vérité et la bienveillance pour les personnes, tout finira par s'éclaircir à la satisfaction générale.

"Avant d'avoir reçu votre dernière, c'est-à-dire lundi 4 courant, j'ai communiqué à la Société Géologique de France, d'abord la Notice sur laquelle vous avez bien voulu mettre mon nom avec le vôtre (*On the Primordial Fauna and the Taconic System*); et ensuite les *Remarks on the Primordial Zone of Canada* de M. Logan. Les observations que j'ai faites à cette occasion, dans le même sens que celles que vous avez présentées à la Société d'Histoire Naturelle de Boston, ont été bien

accueillies. — Je les ajouterai à mes communications de Novembre, 1860, — de sorte que tout cela ne fera qu'une seule notice.

"Je vous ai dit, dans ma précédente lettre, que les revirements de nomenclature ne peuvent avoir aucune influence sur les faits, et vous le sentez tout comme moi.

"Adieu, mon cher Monsieur Marcou, et agréez avec tous mes remerciments l'expression de mes sentiments très distingués.

"J. Barrande."

"Paris, 27 Mars, 1861.

"M. Jules Marcou.

"Mon cher Confrère, ... Sans vous je n'aurais pas reçu de longtemps le *Thirteenth Annual Report of the State Cabinet of Natural History of New York*, qui n'ajoute pas beaucoup à la connaissance des trois Trilobites (de Georgia) en question, mais qui constate que ces fossiles peuvent être nommés *a primordial type*. C'est là le fait important qui restera toujours et dominera la discussion, car je considère les noms génériques *Olenus*, *Paradoxides*, etc., comme très peu importants. Nous devons donc regarder cette déclaration paléontologique . . . . comme nous dispensant à l'avenir de toute discussion oiseuse sur cette matière.

"Je sais vraiment gré au Prof. J. Hall de cette déclaration, qu'il répète de la manière la plus positive par deux fois sur la page 221 de sa *Letter to the Editors of the Amer. Jour. of Sc.* (Sill. Journal, March, 1861) que je viens de recevoir. Je pense que ce numéro du Journal, auquel je ne suis point abonné, m'a été directement adressé par les éditeurs.

". . . . Je trouve d'ailleurs dans l'ensemble de cette lettre, un ton très modéré et que je dois louer, surtout en comparant ce document avec l'annonce de son opposition, qui avait été publiée dans le numéro de Janvier.* Reconnaître qu'il reste à résoudre une grande question dans

* "It is plain to all who take an interest in the progress of geology in the United States, that an active discussion is now imminent on the questions touching Barrande's Primordial zone. In this discussion the Taconic system of Emmons so long suppressed will probably be again put forward. Already the contestants are sharpening their weapons; and we will not anticipate the discussion farther than to intimate that the views of the distinguished French geologist will find a warm opposition at the hands of the New York State Palæontologist, and probably also with some of the gentlemen of the Canadian Survey. The subject is already before the Boston Society of Natural History, where Mr. Marcou appears as the advocate of the Taconic system. . . . . The Introduction [Prof.

la classification des premières faunes paléozoïques, c'est certainement une grande concession de la part de celui qui ne semblait auparavant admettre en aucune façon, que ses propres idées pouvaient être modifiées. Il faut donc que la conviction antérieure et si positive de J. Hall ait fait place à un doute. En fait de doctrine un doute est déjà un acheminement vers une doctrine nouvelle.

" En ce qui touche le groupe de Québec, nous pouvons aussi nous féliciter du grand pas qui a été fait, puisque ce groupe est reporté du sommet à la base de la faune seconde par Sir W. E. Logan. On voit bien par la lettre du Prof. J. Hall, que cette transposition ne lui est pas sympathique. Cependant, il n'exprime pas nettement une négation contraire à cette nouvelle classification. Toute sa discussion paléontologique se borne à démontrer qu'il existe dans l'ensemble des fossiles de la Pointe Lévis, un grand nombre de types de la faune seconde avec quelques types primordiaux. En cela il a parfaitement raison, et il répète pour ainsi dire, mot à mot ce que j'ai dit dans ma seconde lettre à Bronn, publiée dans le 7ème numéro du *Jahrbuch* de Leonhard et Bronn, terminant l'année 1860.

" Il est bien certain, que tout n'est pas encore clair aux environs de Québec ; mais les points obscurs ne peuvent être éclaircis que par des études de détail, qui peut-être demanderont beaucoup de temps.

" En rendant compte, le 4 Février dernier, à la Société Géologique de France, de la lettre (imprimée) de Sir W. E. Logan, j'ai insisté principalement sur ces deux points : 1°. Que le groupe de Québec est placé à la base de la faune seconde, à cause de ses affinités paléontologiques ; — 2°. Que l'ordre stratigraphique des couches indiquées par A — A_1 — A_2, etc., B_1 — B_2, etc., n'est pas encore déterminé. Tant que l'ordre de superposition de ces couches ne sera pas clairement établi, on pourra faire bien des suppositions, que je trouve complètement inutile de discuter en ce moment ; car le fait seul peut nous éclairer un jour et faire disparaître toutes les difficultés actuelles.

" . . . . Je pense d'ailleurs comme vous, qu'il serait inutile en ce moment de discuter ces petites questions de détail, lorsque nous avons déjà obtenu des concessions si considérables et si peu attendues, dans le peu de temps qui s'est écoulé depuis l'origine de ce débat. Vous

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Hall's third volume on the Palæontology of New York] handles with masterly skill the difficult subjects connected with the proper classification of the lower horizons of life in our planet. A review of this important chapter with reference to the views of Barrande will probably appear in our next." — The American Journal of Science, January, 1861, p. 125.

avez remarqué comme moi ces paroles qui terminent les *Introductory Remarks* dans l'article du Journal de Silliman (Correspondence of Joachim Barrande, etc.) du mois de Mars, p. 212, 1861 : '*It seems probable that the sequence contended for by Emmons will turn out to be at least for the greater part the true one.*' Quel contraste entre cette conclusion et l'article de Janvier (p. 125 du même Journal) que vous m'aviez signalé et dans lequel le *Taconic system* était indiqué comme *so long suppressed.* Lorsqu'on voit des dispositions semblables et un changement total de doctrines, dans les savants quí paraissaient auparavant si fermement décidés dans leur opposition, il faut avoir de la patience.

"Attendons les résultats des nouvelles recherches, qui semblent devoir occuper à la fois beaucoup de géologues. Je suis charmé de voir, que vous êtes toujours disposé à consacrer une partie de votre temps à cette grande question : et j'espère que vous contribuerez plus que tout autre à élucider les points sur lesquels nous attendons la lumière. Je serai charmé que cette lumière vienne de vous, précisément à cause de tout ce qui s'est passé. Il serait bien loin de ma pensée et de mes sentiments de regretter de vous avoir pris pour correspondant et pour coopérateur dans cette œuvre purement scientifique. Je ne suis pas de ceux qui peuvent sacrifier leurs sentiments et des relations honorables, à un avantage quelconque. Voilà soixante ans que je pratique cette doctrine, et je ne vois pas de motifs pour faire une exception à votre égard. Je ne veux donc rien changer à nos relations, et j'espère même que ceux qui vous sont le plus opposés comprendront à la fin que, dans les questions scientifiques, il ne faut pas mêler les questions de personnes. J'ai bien remarqué dans l'article du Journal de Silliman (*Correspondence of Joachim Barrande, Sir William Logan, and James Hall, on the Taconic System and the Age of the Fossils found in the Rocks of Northern New England and the Quebec Group of Rocks*, March, 1861, p. 210) qu'on avait mis de côté votre nom.* C'est une petite faiblesse. . . . . Je suis bien persuadé que lorsque vous apporterez de nouveaux faits et des lumières nouvelles dans la question, on sera bien forcé de reconnaître votre existence scientifique et la valeur de vos travaux.

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* The title in the American Journal is, "On the Primordial Fauna and the Taconic System of Emmons, in a Letter to Prof. Bronn of Heidelberg" (Proc. Bost. Soc. Nat. Hist., vol. vii., Dec., 1860, p. 371) ; instead of, "On the Primordial Fauna and the Taconic System, by Joachim Barrande; with Additional Notes, by Jules Marcou."

"Aussitôt que le tirage à part de mes *Documents . . . . et le Système Taconique en Amérique* me sera livré, je vous en expédierai un bon nombre d'exemplaires afin que vous puissiez les distribuer à vos amis. Vous trouverez dans mes *Documents*, etc., un chapitre intitulé, *Transposition verticale de la Faune Primordiale de Suède, par J. Hall.* C'est la rectification d'une grave erreur énoncée par ce savant dans le *Report on the Geology of the Lake Superior Land District*, by Foster and Whitney, p. 318, 1851. J. Hall a essayé en effet dans ce Rapport, de placer les schistes à *Olenus* de Suède au niveau des schistes de Hudson River, ce qui concordait parfaitement avec la transposition du système Taconique. Je ne pouvais pas laisser sous silence une erreur si grave et qui compromettait tous les résultats de mes travaux. J'ai donc démontré qu'il y avait absence complète de tout fondement pour soutenir cette opinion du Prof. J. Hall.

"M. Angelin n'a publié que deux livraisons de sa *Palæontologica Scandinavica.* C'est un ouvrage purement paléontologique et malheureusement beaucoup trop laconique pour les descriptions. Il est tout en latin. La seconde livraison commence par une courte esquisse géologique des étages ou *Regiones* constituant le terrain. Cette esquisse occupe à peine neuf pages. Du reste, bien que cet ouvrage soit important à mes yeux, à cause des faits qu'il constate, beaucoup de géologues seraient disposés à faire des reproches à l'auteur, d'une côté parce que ses descriptions sont très incomplètes, et de l'autre parce que les figures qu'il donne, laissent beaucoup à désirer. Pour moi, qui connais M. Angelin, pour avoir passé avec lui plusieurs mois à Prague, en 1855, et à Paris, en 1860, j'excuse volontiers ces deux défauts et même un certain manque d'ordre, en considération des circonstances difficiles qui pèsent sur lui, et aussi de la confiance qu'on doit avoir dans sa conscience scientifique, qui est très droite. Vous verrez dans mes *Documents*, etc., que, dans diverses circonstances, il a voulu que son opinion fut publiée comme en parfaite harmonie avec la mienne, notamment en ce qui touche les Trilobites de Georgia et la transposition verticale des schistes à *Olenus* de Suède, dont j'ai parlé plus haut.

"J'estime beaucoup, comme vous, le Colonel Jewett que je connais depuis longtemps, par les témoignages de M. de Verneuil. Je lui ai récemment écrit pour le remercier d'avoir bien voulu me transmettre les ouvrages du Prof. Emmons. Je suis charmé de vos bonnes relations avec lui, et je crois que s'il voulait sortir de son rôle trop modeste, sa voix ne manquerait pas d'avoir une grande influence dans l'importante question qui occupe en ce moment les esprits.

"Je vous prie d'exprimer plus particulièrement à Madame Marcou mes sincères remercîments pour ses traductions * aussi élégantes que fidèles. Agréez mon cher confrère l'expression de tous mes sentiments très distingués.

"J. BARRANDE."

After this successful beginning, the Taconic question demanded minute and careful study in the field in order to be fully decided. Its adversaries had conceded something; it became necessary to pursue the research, and to clear up the stratigraphy of the borders of Lake Champlain and the environs of Quebec. Urged by Colonel Jewett, Barrande, Agassiz, and Billings to undertake this work, as an extract from a letter of Billings to Colonel Jewett will show, I resolved to devote myself to this difficult and ungrateful task; and in September, 1861, I started for Vermont.

"MONTREAL, July 30, 1861.

"MY DEAR COLONEL JEWETT:—

". . . . I send you by express to-day a Trilobite from the Red Sandrock of Vermont. It is a *Conocephalites* allied to *C. minutus* of the Potsdam, but still a distinct species. This Trilobite proves very clearly that the Red Sandrock of Vermont is either the Potsdam or the base of the Calciferous. The genus *Conocephalites* is a true Primordial type. No species of this genus is found above the base of the Lower Silurian. This puts an end to the idea that the Red Sandrock is the *Medina sandstone*. Besides, I have other evidence. I lately spent three weeks at Phillipsburgh on Missisquoi Bay examining into the age of this formation. At Phillipsburgh the Calciferous † is laid bare over an area of eight miles in length by about three in width. Along the shore of the bay it forms a precipice, from fifty to one hundred feet high, for three miles. The base of the cliff is composed of slate as at Sharp Shins. The Calciferous rests upon the slate unconformably. [This is a mistake, for the limestone is enclosed in the slates. — J. M.] I found here (in the Calciferous) about forty species, most of them new. Of the described species I

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* Mrs. Marcou translated into English the three letters of Barrande of the 29th May, 16th July, and 14th August, 1860, published in the Proc. Bost. Soc. Nat. Hist., vol. vii. p. 369.

† The Calciferous does not exist at Phillipsburgh. Billings took the Phillipsburgh group, which corresponds to the Point Lévis group, for the Calciferous of Chazy Village, a synchronism which cannot be maintained after a visit to the two places. — J. M.

found *Maclurea matutina* and *M. sordida* in great abundance; also the species figured by Hall under the name of *Turbo dilucula*. *Euomphalus uniangulatus* occurs here but rarely. I shall describe them all shortly. Not a vestige of any Medina sandstone or Middle Silurian species is to be seen. I followed the Calciferous back three miles, and then came on the Red Sandrock. The two formations are in contact, but I could not ascertain which is the uppermost, on account of the disturbed state of the strata. I then traced the Red Sandrock down into Vermont. Hearing that Dr. Hall of Swanton had found Trilobites in it, I called upon him, and he accompanied me to the place. It is just two miles south of the Province line, and about one mile or a little more east of Highgate Springs. It is in a hill about a hundred and fifty yards east of the house of a man by the name of Church. We found a number of specimens and a small *Theca*. They are exactly such forms as I expected to find. I believe these are the only fossils found in the Red Sandrock, and as they prove this rock to be the base of the Lower Silurian, what are we to call the immense formation of slate that lies beneath it? Surely not Hudson River group.

"In about three weeks I intend to go out to the Eastern townships again, and will let you know the results. You say that Prof. J. Hall 'still declares that the position of Sir William Logan does not affect the stratigraphy in the least.' Sir William's position brings down the Quebec rocks from the top of the Lower Silurian to the bottom. It makes all those rocks in Vermont (called Medina sandstone) either Potsdam or Calciferous, and consequently the slates which can be seen lying below them at Snake Mountain, at Sharp Shins, and at Phillipsburgh are older than the Lower Silurian.

"It is upon the age of these Vermont rocks that the whole Taconic question depends. If they are Medina sandstone, and if the slate beneath them is Hudson River, then there is no Taconic system. But if the Red Sandrock of Vermont is Calciferous or Potsdam, then Emmons is right. Sir William concedes to the fullest extent that they are of the age of the Calciferous or Potsdam, and therefore he admits all that Emmons requires. If that does not affect the stratigraphy, I do not know how it can be affected. As I have often stated in my former letters, it will be some time before all will be cleared up.

"It is unfortunate that in New York there are no active and unprejudiced geologists to enter into this vast field of research. All that has been done during the last two years (I mean in the way of publication) has been effected in a roundabout way through foreign geologists. It should have been done in New York. I hope Jules Marcou

will soon take up the subject. He should examine Snake Mountain, Sharp Shins, the Red Sandrock at Highgate, and the cliff along the shore from Phillipsburgh to the mouth of Rock River on Missisquoi Bay.

"I could publish a great deal myself, but cannot well do so. You are an old officer, and know well what *subordination* means. I fear I have made this badly written letter too long.

"Yours very sincerely,

"E. BILLINGS."

The principal results of my first exploration, in September and October, 1861, were, 1st, a complete confirmation of the *Taconic system;* 2d, the absence of metamorphic rocks in the upper Taconic from Snake Mountain and Georgia, Vermont, to Point Lévis; 3d, the creation and exact position of the divisions of the "Georgia slates" and "St. Albans group" at the base of the upper Taconic; 4th, the maintaining the Potsdam sandstone in the upper Taconic and the Primordial fauna which it covers, as I had proposed in the first notice published jointly with M. Barrande.

These views were presented to the Boston Society of Natural History at the meeting held November 6, 1861, and a notice, entitled, "The Taconic and Lower Silurian Rocks of Vermont and Canada," was published in the Proceedings, vol. viii. p. 239, November, 1861, which sums up the facts obtained.

Mr. Barrande wrote me the following letter in regard to my researches at Point Lévis and Georgia.

"PRAGUE, 9 Nov., 1861,
Kleinseite, No. 419 Choteksgasse.

"MON CHER MONSIEUR MARCOU: —

"J'apprends avec beaucoup de plaisir par votre lettre du 2 Octobre, que vous avez fait votre voyage d'exploration dans le Vermont et dans le Canada, avec succès et satisfaction. Je suis à votre disposition pour présenter à la Société Géologique de France le mémoire que vous vous proposez de rédiger cet hiver, sur vos observations.

"Si vous établissez nettement la succession des formations de la Pointe Lévis, ce sera un point fort important. La succession des formations observée à Belle Isle, par Mr. Richardson vient fort à propos pour confirmer toutes nos vues. C'est magnifique, suivant votre expression, et la lumière se fait de plus en plus, avec une rapidité que

nous n'avions pu espérer. Je pense que Mr. Billings me donnera quelques détails sur cette suite de fossiles de Terre-Neuve.

"Je viens de lire un *Review* de mes *Documents*, etc., par Mr. Sterry Hunt, qui me l'a addressée avec quelques mots de politesse. Elle a paru dans le *Canadian Naturalist*, 10 pages. Le grand fait de la faune Primordiale en Amérique n'est plus contesté, mais on voit qu'on accorde avec regret à Mr. Emmons le mérite de l'avoir devinée, tandis que le premier paléontologue américain l'a méconnue. Il faut bien cependant se résigner devant les faits historiques. Il paraît que mon chapitre sur la *Transposition verticale de la Faune Primordiale par le Prof. Hall*, a touché un point sensible, puisque Mr. Hunt croit devoir reproduire l'excuse que j'ai mentionnée en faveur de son ami.

"Vous savez sans doute que le Prof. Geinitz de Dresde vient de publier le premier volume (fossiles) du *Dyas*. Ainsi voilà votre *Dyas* installé en Allemagne.

"J. Barrande."

One important palæontological memoir by Billings appeared in August, 1861, (Canadian Naturalist and Geologist, vol. vi. p. 310, Montreal,) entitled, "On some of the Rocks and Fossils occurring near Phillipsburgh, Canada East." In this work, as in his memoir "On some new Species of Fossils from the Limestone near Point Levi, opposite Quebec," August, 1860, he considers both faunæ as very similar, and having even thirteen identical species, and both as indicating the lower part of the "Calciferous sandrock.

1862. — I give here extracts from Barrande's letters written during the first eight months of 1862.

"Prague, 3 Mars, 1862.

"Mon cher Monsieur Marcou: —

". . . . Je ne comprends pas pourquoi Mr. Billings, qui auparavant m'adressait de longues lettres, a complètement cessé de m'écrire depuis un an. Il ne m'a pas même accusé réception de mes *Documents*, etc. Sir W. Logan s'est retranché de même dans le silence. Je ne crois pas cependant avoir démérité en rien de ces Messieurs, puisque vous trouvez que j'ai beaucoup trop fait valoir les travaux du *Geological Survey of Canada*.

"En compensation, et à ma grande surprise, j'ai reçu il y a peu de temps une lettre de J. Hall. Je ne m'attendais pas à cette communication, après la lettre publiée l'an dernier par lui dans le Silliman's Journal, vol. xxxi. p. 220, March, 1861. En effet J. Hall paraît avoir

fait depuis lors de très louables réflexions, et il m'exprime le regret d'avoir écrit cette lettre, qui contraste beaucoup avec les opinions très nettes qu'il professe aujourd'hui. Il est du même avis que moi, non seulement sur la nature primordiale des Trilobites de Georgia, mais encore sur la position stratigraphique que doivent occuper les roches de cette localité dans la série verticale. Il renonce donc complètement à ranger ces roches dans l'Hudson River, et il reconnaît qu'elles doivent être reportées vers la base de toute la série. En même temps, il m'envoie deux sections gravées, présentées par lui à l'Association of American Geologists and Naturalists, en 1845–46. Or ces sections indiquent les schistes de Georgia comme immédiatement superposés au grès de Potsdam, et en stratification concordante avec ce dernier. C'était le résultat d'explorations faites par J. Hall en 1844–45 et concordantes avec les vues de Eaton sur ces contrées. J. Hall me dit qu'il n'avait abandonné ces opinions primitives, résultant de ses propres observations sur le terrain, que par déférence pour l'autorité de Sir William E. Logan et de Mr. Hunt, qui lui ont persuadé que tout le groupe de roches en question se trouvait au niveau du groupe de Hudson River.

"Voilà donc l'assentiment de J. Hall sur les deux points principaux en question. Quant aux points secondaires que vous débattez, il est aussi à espérer qu'on finira par s'entendre de même.

"J'ai étudié votre notice du 6 Nov., 1861 (*The Taconic and Lower Silurian Rocks of Vermont and Canada*, in Proceed. Boston Soc. Nat. Hist., vol. viii. p. 239). Tout ce qui regarde le Vermont me paraît très clair, et du point où je suis placé il n'y a pas la moindre observation à faire sur la succession verticale que vous indiquez. Seulement, j'aurais été porté à maintenir les *Lingula flags* (Highgate Springs) avec le Potsdam, par ce que ce dernier a toujours été caractérisé par ses Lingules. En ce qui touche les environs de Québec, votre notice est trop concise pour que je me figure bien la succession verticale; notamment au sujet de la colline de la Redoute. Vos profils nous expliqueront cela, je pense; et c'est très nécessaire de l'expliquer, si c'est possible, après les indications si incomplètes de Sir W. Logan.

"Mille choses aimables à notre ami Mr. Agassiz. Je pense souvent que la guerre civile doit beaucoup le contrarier pour la publication de son grand ouvrage (*Contributions to the Nat. Hist. of the U. S.*), et je partage bien toutes ses contrariétés à ce sujet. Je vous prie aussi de le remercier pour l'envoie de ses deux notices au sujet des *Homologies des Radiaires* qui m'ont beaucoup instruit.

"J. Barrande."

"P. S. Le second volume du *Dyas* de Geinitz, qui doit exposer la partie stratigraphique n'a pas encore paru. Il y a avec lui d'autres collaborateurs, dont l'un a étudié le terrain en Russie."

"PARIS, 3 Mai, 1862.

"MON CHER MONSIEUR MARCOU:—

". . . . Le lundi, 28 Avril, jour de la séance de la Société Géologique, j'ai fait une courte communication au sujet de la lettre de James Hall dont je vous avais parlé dans ma dernière du 3 Mars. J'en ai exposé le contenu en quelques mots, en rappelant que l'année dernière, j'avais communiqué une autre lettre du même savant, sur le même sujet, et dans un sens très différent. J'ai fait remarquer que J. Hall, en reconnaissant aujourd'hui que les couches renfermant les Trilobites primordiaux doivent être rapportées à la base du Silurien Inférieur et non au Groupe de Hudson River, a réellement mis fin à la discussion de la question principale. Cette question étant la seule dans laquelle un géologue qui n'a jamais vu le terrain, puisse exprimer une opinion, il me semble qu'à l'avenir mon rôle doit se borner à être simple spectateur des différences d'opinion qui peuvent encore exister au sujet des questions secondaires. La faune Primordiale étant reconnue par tout le monde, et attribuée à son véritable horizon, en Amérique comme en Europe, ceux qui comme moi portent intérêt à ce grand fait, doivent patiemment attendre que les recherches locales jettent la lumière nécessaire sur les divers points contestés.

"À ce sujet, j'ai naturellement mentionné vos travaux récents et votre voyage dans le Vermont et le Canada, dans le but d'établir l'ordre de succession des formations fossilifères les plus anciennes. J'ai cité les sections que vous avez données dans votre communication du 6 Novembre, 1861, à la Société d'Histoire Naturelle de Boston, et je reproduirai au moins celle de Vermont dans ma notice (*Bulletin Soc. Géol. France*, 2ème série, vol. xix. p. 721, Paris, 1862).

". . . . Comme il n'existe pas de Graptolites dans la faune Primordiale d'Europe, la présence et la grande fréquence de ces fossiles dans la faune Primordiale d'Amérique, doit être constatée de la manière la plus authentique. Vous ne paraissez pas douter de ce fait, d'après vos indications, et en cela vous vous trouvez d'accord avec le Prof. J. Hall, qui m'exprime la même opinion dans sa lettre. Vous savez qu'en diverses circonstances j'ai signalé le privilège d'antériorité de la zône silurienne du nord, et plus spécialement de l'Amérique, par rapport à la zone du centre de l'Europe. Le développement des Graptolites dans la faune Primordiale viendrait fort à propos pour confirmer ces

vues, qui ont déjà été adoptées par beaucoup d'autres géologues. Vous concevrez aussi que des faits de cette nature confirment naturellement et d'une manière très générale ma doctrine des Colonies.

"M. Delesse a eu la complaisance de me remettre votre *Carte Géologique de la Terre;* je vous en suis très reconnaissant. C'est un immense ouvrage, par les recherches qu'il a dû exiger dans toute la littérature scientifique. Nous profiterons tous, pour notre instruction, de votre beau travail. "J. BARRANDE."

"PARIS, 24 Juin, 1862.

"MON CHER MONSIEUR MARCOU:—

". . . . Vous verrez en lisant ma brochure, *Défense des Colonies,* II.; que MM. les géologues de Vienne ne se sont pas gênés pour faire une carte géologique fantastique, ou en d'autres termes, pour altérer les faits et les accommoder à leurs idées préconçues. Au fond de tout cela il y a de tristes préoccupations, et je ne puis me dissimuler que je constitue par ma personne la *Colonie* qu'on avait le plus en vue dans cette attaque. On croyait sans doute que je ne retournerais plus en Bohême, après une absence de plus de dix-huit mois, mais je montrerai de la manière la plus incontestable, que le systême des plis imaginé contre les Colonies repose uniquement sur des faits controuvés ou altérés.

"Je vois que vous admettez le renversement des couches du Taconique et que vous considérez le grès de Potsdam comme se présentant *sous forme de couverture brisée et en échellons.* Il paraît que cette disposition n'est pas vue de même par tout le monde, et notamment par Mr. Billings qui indique à l'Est de Swanton une localité où l'on voit les schistes noires à *Paradoxides* (*Olenellus*) alternant conformablement avec le *Red Sandrock.* Il y aura donc à ce sujet discussion prolongée tant que cette contrée ne sera pas étudiée et décrite avec tous les documents désirables. Je pense que c'est à cela que vous travaillez, puisque vous avez différé la publication de votre travail, afin d'avoir le temps de revoir les localités de Georgia et de Québec. Une si grande question dont la solution embrasse une si vaste surface de terrain, demande certainement beaucoup de temps et d'étude.

"J. BARRANDE."

"PARIS, 26 Août, 1862.

"MON CHER MONSIEUR MARCOU:—

"Je pars après demain, pour aller me reposer à Prague de toutes mes fatigues dérivant soit de mes affaires à Paris, soit de mon séjour d'un mois à Londres, d'où j'arrive.

"Ce voyage en Angleterre n'a été que très accessoirement scientifique, par ce que je ne l'ai fait que pour accompagner Monsieur le Comte de Chambord à la grande Exposition Internationale. J'ai cependant vu quelques géologues. Sir W. Logan avait quitté Londres la veille de mon arrivée. Il m'a envoyé ici 464 pages de sa *Geology of Canada*, 1862. L'ouvrage n'est pas achevé, mais le sera bientôt sans doute. Au sujet du groupe de Québec il reproduit ce qu'il a déjà dit, en indiquant que le sujet est encore à l'étude. Je pense que le dernier mot dépendra des documents fournis par Mr. Billings, qui continue à distinguer ses calcaires Nos. 1, 2, 3, 4, dans ses *new species* en attendant sans doute ses études stratigraphiques sur les lieux. Il serait fort à désirer que vous puissiez vous entendre avec lui, car le fractionnement des opinions ne peut qu'entraver la solution finale des questions à résoudre, à l'appui de la grande question déjà résolue.

"Je suis charmé que vous ayez fait de bonnes études sur les lieux, et j'admire beaucoup la conviction qui a surgi subitement en vous, au sujet de la doctrine coloniale. Depuis que j'ai énoncé cette doctrine, si contraire aux idées reçues, je me suis bien gardé d'en presser l'adoption, même dans l'esprit de mes amis. Les faits et les observations doivent seuls amener la croyance, pour qu'elle soit solide. Si vous lisez la seconde brochure de ma *Défense des Colonies*, vous verrez que par la multitude de faits nouveaux que j'indique dans le bassin de la Bohême ; que je ne m'étais nullement hâté de donner à mes amis, pas plus qu'à mes adversaires, la connaissance de tous les documents qui ont servi de bases à ma doctrine. Par suite de la polémique engagée, je suis obligé de dévoiler successivement ces faits, et je n'en suis pas encore au bout. J'en ai assez dit pour montrer que les prétendues études de mes contradicteurs ne sont autre chose que des combinaisons arbitraires, qui manquent à la fois de fondement réel et de sincérité. À la suite de ces débats, je ne doute pas que l'idée des Colonies ne soit adoptée dans la science, comme la faune Primordiale, les métamorphoses des Trilobites, etc., qui ont aussi soulevé bien des contradictions.

"Il est fort possible que certaines Colonies représentent des centres de création. En indiquant cette conception, je me suis décidé pour l'immigration à cause des circonstances propres à la Bohême. Je ne suis pas juge pour les autres pays ; et mon choix du nom de *Colonies* ne peut être apprécié que d'après mon point de vue, auquel il m'a paru logiquement adopté.

"J. Barrande."

The experience of 1861 had convinced me of the need of very close and careful study on several chosen points in order to reach any precise results as to the strata existing between the "schists of Georgia" and the "Utica slate." The exploration of this year was therefore devoted to Swanton, Phillipsburgh, and Chazy on Lake Champlain, and to Point Lévis near Quebec. First, each bed at Point Lévis was studied with care, at the east of the village and near the railway station; and in the month of July I was convinced that what had been considered as *beds* of limestone and conglomerate were only *lentils* enclosed in the schist. This discovery explained several outcroppings of magnesian limestone which had embarrassed me the preceding year at St. Albans Bay, at Swanton, and at Highgate.

Dr. Emmons and Colonel Jewett had considered similar formations in the neighborhood of Troy, New York, used for making lime, and also those along the line of the Upper Taconic from Canada to the Hudson River, as *bags* of Silurian limestone (Trenton or other) which were deposited in *holes* or *cracks* of the black Taconic slate. They had seen that, at several of these quarries, the lime was exhausted, there being no more limestone. For them these bags of limestone were the remains of the Lower Silurian which had extended thus far at the time of the deposit, but which subsequent denudations had carried off, leaving these bags of limestone to witness to their former extent. Some rare and badly preserved fossils were found in these bags of limestone, identical with, or at least very similar to, six or eight Silurian species from the groups of Chazy and Trenton.

The proof once reached, that the limestone lentils of Point Lévis were of the same age with the schists which enclosed and shut them in too surely to admit the doubt of a later deposit, I went directly to Swanton, seeking to verify the same fact in the limestones of this eastern shore of Lake Champlain. I drafted exactly the surface appearances, and studied in detail several lime quarries, quite common in this region. I found everywhere that the limestones were *lenticular masses*, some very limited in size, like boulders; and others, on the contrary, having the characteristic form of lentils; and all so well enclosed in the schists that they were penetrated by them, or they were thrust into them like wedges.

Further, I found these limestone lentils scattered at all levels of the Upper Taconic, from its base in the schists at the east of the town of St. Albans, to the borders of Lake Champlain in the schists of Swanton; they were singularly placed, sometimes isolated, sometimes in large

agglomerations, and sometimes absolutely wanting over large surfaces where the schists only were found.

The next step was to revisit with care the Isle La Motte, the peninsula of Alburgh, Chazy Landing and Village, Keeseville, and Potsdam. These typical localities of the Calciferous, of Chazy, Trenton limestones, and Utica slate, already visited by me in 1849, are very rich in fossils, and easy to study, and at a distance of only from three hundred yards to one mile from the Taconic region of the eastern part of Lake Champlain. When there I saw plainly the necessity of giving up all idea of identifying their strata with those of Georgia, St. Albans, Swanton, Highgate, and Phillipsburgh.

Near to Chazy and Potsdam, I observed that the Calciferous sandrock, and consequently all the Lower Silurian, rested in discordance of stratification on the Potsdam sandstone, — at least a discordance of sixteen degrees. I had foreseen and indicated this in the additional notes to the letters of Barrande in our memoir of 1860 (On the Primordial Fauna and the Taconic System, p. 380), in which I say: "I am not sufficiently acquainted with its (the Potsdam group) distribution and position in regard to the Taconic and the Calciferous sandrocks to give a decided opinion based on stratigraphical grounds, but from the description of Prof. Emmons in his *Taconic system*, and from what I have seen at Little Falls, the Calciferous sandrocks are certainly very differently distributed from the Potsdam, and a dislocation and disturbance of strata have taken place between the two groups."

It was a happy discovery, for with the palæontological proofs of the strictly primordial character of the small fossils found at Keeseville and Highgate, there was no longer a doubt that the Potsdam sandstone belonged to the Taconic, as the covering and last term of the Primordial Zone in America.

I published a letter addressed to Barrande, August 2, entitled, "Letter to M. Joachim Barrande on the Taconic Rocks of Vermont and Canada," with a plate of a "Comparative Tabular Section of the Upper Taconic Rocks in Vermont and Lower Canada." This letter for the first time mentions the existence of calcareous lentils or lenticular masses of limestone in the Taconic slate, encloses the "group of Phillipsburgh" and the "Swanton slates" between the "Georgia slates" and the "Potsdam sandstone," and contains the opinion that there are no Calciferous sandrocks either at Phillipsburgh or at Point Lévis. Finally, the calcareous lentils of Point Lévis and Phillipsburgh are spoken of as precursory centres, or Barrande Colonies; Colonies of the second fauna enclosed in the Primordial one.

There remained a very difficult question to settle, — the presence at Highgate Springs of a group of rocks, which palæontologists persisted in calling Lower Silurian, thus indicating the existence of Black River, Trenton, and even Utica slate.

I passed the autumn of 1862 in reviewing attentively the country from Phillipsburgh to Shoreham, Vermont, accompanied by the late Dr. Hall and the late Rev. J. B. Parry of Swanton, two skilful geologists, who spared me much time and fatigue, by taking me to the fossiliferous localities. In August, 1863, I again visited Point Lévis, Vermont, and the State of New York. Finally, in 1873 and 1874, I passed from four to five months at Highgate Springs, repeatedly studying every square yard of the ground, and at length determined that the rock between the Franklin Hotel and Lake Champlain was not a Silurian wedge driven into the Taconic, but an agglomeration of lenticular limestone with schists, containing the colonies of the Second fauna enclosed in the Primordial one.

But let us go back; for my memoir with a geological map of the Taconic of the borders of Lake Champlain was not published till 1881.

1863. — At the beginning of this year, I received from Barrande the following letter: —

"Prague, 17 Janvier, 1863.

"Mon cher Monsieur Marcou: —

"Je regrette beaucoup que ma lettre du 18 Octobre ne vous soit pas parvenue [a lost letter]. D'abord parce qu'elle exprimait mes remerciements pour votre brochure (*Letter to Joachim Barrande on the Taconic System*, etc.), et ensuite parce que j'y avais ajouté quelques observations qui me paraissaient importantes, avant la rédaction définitive du mémoire que vous voulez faire paraitre dans le Bulletin de la Soc. Géol. de France. [It did not appear until 1881.]

"Le point important est celui-ci. Dans votre lettre imprimée du 2 Août, 1862, et dans les *Tabular Sections* qui l'accompagnent, vous indiquez un grand nombre de fossiles de la faune seconde trouvés dans les lentilles calcaires du groupe de Phillipsburgh, environ cinquante espèces. Parmi ces fossiles vous indiquez deux *Dikelocephalus* et un *Menocephalus* comme appartenant à la faune primordiale. Ce fait est certainement très intéressant, mais considéré seul, il pourrait être interprété simplement comme indiquant le passage successif et par voie ordinaire de mélange, entre la faune primordiale et la faune seconde.

"Pour que vos lentilles calcaires jouent le même rôle que mes colonies de Bohême, il faudroit encore montrer la faune primordiale continuant à exister et florissante, soit dans les schistes proprement dits

de Phillipsburgh qui enveloppent les lentilles, soit dans les schistes de Swanton qui sont au dessus.

" Il y a bien des *Conocephalites* indiqués dans votre grès de Potsdam, mais c'est un horizon éloigné, et dont la position stratigraphique dans cette série pourra vous être contestée, autant que je puis en juger parceque vous en dites en peu de mots.

" Peut-être avez-vous seulement omis de citer les espèces primordiales dans les schistes de Phillipsburgh et au dessus. Dans ce cas, la lacune de votre lettre sera aisée à combler. Mais dans le cas contraire, il serait bien important de découvrir quelques fossiles dans ces schistes, ou immédiatement au dessus pour établir la parité avec mes Colonies. Vous aurez remarqué que je définis mes Colonies comme une *apparition intermittante des avants-coureurs de la faune troisème au milieu de la faune seconde.* En effet, j'ai toujours montré à tout venant les fossiles caractéristiques de la faune seconde, en place, au dessus comme au dessous de mes Colonies. Tâchez donc de compléter ce point si cela vous est possible.

" 2°. Les relations du grès de Potsdam avec les formations du système Taconique n'étant pas assez développées jusqu'ici, ne sont pas bien claires pour moi, et devraient être établies très nettement pour aller au devant de toute objection.

" 3°. Le renversement général du systême Taconique, que vous indiquez seulement en passant comme un fait hors de doute, aurait aussi besoin d'être éclairci ; car c'est ce renversement qui rend plus difficile l'intelligence des relations du Potsdam avec la série inférieure.

"4°. Vous considérez vos lentilles calcaires comme des centres de création. J'admets volontiers cette interprétation comme très plausible, d'après nos idées actuelles de la succession des faunes.

" Cela posé je vous prie de considérer que les espèces de la faune seconde qui font leur première apparition dans ces centres, disparaissent ensuite, de la contrée, durant une période de temps fort longue et représentée par les dépôt des schistes de Swanton et du grès de Potsdam. Si elles reparaissent dans les mêmes parages, c'est dans la faune seconde développée au dessus du grès de Potsdam. Cette longue disparition ou intermittence ne peut avoir eu lieu que par deux migrations successives, à deux époques très éloignées l'une de l'autre, savoir: d'abord après le dépôt des lentilles calcaires (départ du centre de création), et ensuite retour après la disparition de la faune primordiale.

" On arrive donc toujours forcément à l'idée des migrations, qui sont implicitement exprimées dans la dénomination de Colonies, ainsi que je l'ai expliquée en diverses occasions.

"Je vous soumets amicalement ces observations afin que vous en fassiez l'usage que vous trouverez convenable.

"Vers la fin de Mars j'arriverai à Paris, et je m'occuperai des fossiles que vous m'avez expédiés par le Hâvre. Il est probable que la plupart des espèces ont été déjà nommées par Mr. Billings, ou le seront avant peu. Pour moi, je ne cours pas après cette conquète, car j'ai encore à moi plus de fossiles que je n'ai pu en étudier et nommer jusqu'ici. — Ce que j'espère, c'est de profiter de votre aimable communication pour bien apprécier les contrastes entre les faunes primordiale et seconde du Nord de l'Amérique; si toutefois ils existent comme en Bohême ce que j'ignore.*

"Vous saurez que durant ces dernières années j'ai surtout travaillé à compléter la connaissance de la première phase de la faune seconde, — ma division d^1.

"J'ai porté à quarante-huit espèces le nombre de ses Trilobites, qui n'était que de trois en 1852. Les autres fossiles sont relativement moins nombreux dans d^1. Ainsi les Trilobites y prédominent comme dans la faune primordiale. Cependant malgré cette grande analogie dans leur composition zoologique; malgré la proximité stratigraphique, il n'a été découvert en Bohême aucune espèce commune à la faune primordiale et à la phase originaire de la faune seconde. C'est un fait très remarquable, mais, je le répète, je ne prétends pas et je n'attends pas qu'il se répète ailleurs.

"La polémique sur les Colonies n'a pas fait un pas, parce que mes contradicteurs n'ont pas encore répondu à mes deux brochures (*Défense des Colonies*, I. et II.). Voilà un an qu'ils méditent leur réponse. Il est difficile de répondre en effet, quant il s'agit de justifier de véritables faux en matière scientifique. Haidinger qui était si ardent, m'a écrit il y a quelques semaines, qu'il *avait des dispositions plus conciliatrices que belliqueuses*. Nous verrons comment il cherchera à concilier la vérité avec la fausseté. C'est difficile, et je ne me prête pas à des accommodements de vanité aux dépens de la vérité.†

"J. BARRANDE."

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* This large box of fossils from Georgia, Swanton, Phillipsburgh, Point Lévis, Braintree, and Newfoundland was never opened, and Barrande returned it to me in Paris, in 1867, having really no time to devote to it. The contrast between the primordial and the second faunæ does not exist in America, nor Scandinavia, nor England, as it does in Bohemia, where special circumstances have arrested life during the end of the deposits of the Taconic system. — J. M.

† This last phrase is very characteristic. Barrande was immovable when the truth was concerned, as well in science as in political affairs. — J. M.

In May, 1863, Sir William E. Logan published his "Geology of Canada, 1863. — Geological Survey of Canada; Report of Progress from its Commencement to 1863; accompanied by an Atlas of Maps and Sections." A large volume of more than 900 pages (Montreal, 8vo).

Let us notice first the contradiction between the text and the geological map.

"The Quebec Group," or Chapter XI., is placed in the description of the stratigraphic series between Chapter X., "The Utica and Hudson River Formations," and Chapter XII., "The Anticosti Group and the Guelph Formations"; that is, between the second and third faunæ. But in the text (p. 225) Logan says: "Although from their geographical position apparently superior to the Hudson River formations, these rocks belong in reality to an older group, which is developed to a great extent in Eastern Canada, and presents somewhat different characters in the various parts of its distribution. The rocks of this series are still under examination, and the descriptions now given may hereafter require to be somewhat modified."

Thus, in 1863, Logan reconsiders the opinions expressed in his letter to Barrande, of 1861, and his acquiescence in the opinions long maintained by Emmons. In the Geological Map of Canada, instead of placing the Quebec group above the Hudson River, as he does in the text, he places it below the Birdseye and Black River group; and even more, he identifies it with the Chazy limestone and the Calciferous group, an error as glaring as putting the Georgia slates with *Olenellus*, above the Utica and Lorrain groups.

In Chapter II., "Geological Nomenclature," (p. 20,) the Quebec group represents the Calciferous and the Chazy, and, further, the Calciferous is identified with the Lévis, and the Chazy with the Sillery; two errors as incomprehensible as the position of the *Olenellus* schists of Georgia at the top of the second fauna. Towards the close of the volume (p. 836), the supplementary Chapter XXII. gives the results of his researches in 1862 and 1863. The Quebec group is again described at length, from pages 844 to 880. In the Atlas accompanying, sections are given, and a geological map on a large scale, with the title, "Map showing the Distribution of Rocks belonging to the Potsdam, Quebec, and Trenton Group on the east side of Lake Champlain in the Neighborhood of the Line between Canada East and Vermont." In the explanation of the colors, there are only three divisions, the Trenton, the Quebec, and the Potsdam, arranged in their supposed order of superposition.

According to Logan the Potsdam includes not only the Red Sandrock, but the Georgia slates and the St. Albans group; an approximative thickness of from 3,700 to 4,000 feet. He also puts into it, between Swanton and Highgate Falls, schists with lentils of magnesian limestone of the Phillipsburgh group. It must be remembered that the Red Sandrock rests in discordant stratification upon the schists of Georgia, the group of St. Albans, and that of Phillipsburgh; thus giving to the Potsdam, as described by Logan, an extension and a mixed composition such as this group does not possess at Potsdam, nor anywhere in the State of New York, where it was created.

The Quebec group comprehends the Phillipsburgh group and that of St. Albans, beginning at Highgate Falls and rising towards the north. As this group is found throughout the region his map covers, below the Red Sandrock or Potsdam, he is obliged to see along the whole course of accidental contact a fault, recognized at certain points and supposed at others, where he inscribes *supposed fault*. In the western part no fault is seen, and he does not seek to explain why his Potsdam is there superposed upon the Quebec group. All the schists of Swanton and Highgate Springs are called "Trenton."

After a long and very detailed study of all the region represented on this map, I could not find a *fault* anywhere. There is discordant stratification between the Red Sandrock and all the other beds, which are all older; and I found neither Calciferous, Chazy, Trenton, nor Utica slate. The result of these studies was given in my "Carte Géologique des Bords du Lac Champlain entre Georgia (Vermont), Chazy (New York), et Phillipsburgh (Canada)." (See Bulletin Soc. Géol. de France, Tom. IX. Plate I., 1881, Paris.)

With these two documents any practical geologist can go upon the ground and form an opinion as to the value of these different investigations.

I have given more attention to this volume, "Geology of Canada, 1863," because Sir W. E. Logan, having recognized the value of the observations of Emmons in his Letter to Barrande, 31 December, 1860, here tries to suppress the *Taconic system;* first by creating the *Quebec group*, and then by giving to the *Potsdam sandstone* a much greater vertical extension than it possesses at Potsdam itself, and, lastly, by putting directly below and in contact with the Potsdam the *Huronian* series, created at the expense of the *Lower Taconic.*

1863–1881. — The palæontologists, while extending the primordial fauna above and below the Georgia slates, were always met by apparitions of certain forms of the second fauna which disconcerted them;

they seem from 1862 to 1881 to have remained stationary, while the old adversaries of the Taconic system, taking courage, have made great efforts to suppress it entirely. But as I have avoided citing the attacks and criticisms of the first period of the history of the Taconic system, I will not mention the numerous criticisms appearing from 1861 to 1881, as these publications have brought no new facts or elements into the Taconic question.

Justice should be rendered to the labors of the palæontologists, more especially those of Billings, S. W. Ford, Whitfield, Hart, and Matthews. Billings did not give all he promised. Placed in a subordinate position in the Geological Survey of Canada, and succeeding as palæontologist a *savant* with whom he disagreed almost from the beginning, — affected by a cruel malady that completely paralyzed his power of observation in the field, — he died at a comparatively early age, and was thus prevented from showing his full powers and doing what was to be expected from so good an observer. In truth, no American palæontologist has ventured to touch the stratigraphic question. No one has been willing to render palæontology subject to stratigraphy studied carefully on the ground. If Barrande had been like them, he would never have found his " Colonies " !

Stratigraphists are as subject to error as other men, without doubt; if they observe under the influence of a preconceived idea, they are often mistaken. This occurred in Bohemia to Lipold, Krejci, and Marr. But when, like Barrande, they study the ground with the sole object of finding the veritable structure of the rocks and their relative ages, that is, the truth as it exists, they are seldom deceived.

1881. — After twenty-one years of study in the field and researches in collections I published the result of my research on the upper part of the *Taconic system* or *Taconic* proper of the eastern side of Lake Champlain. The memoir appeared in the *Bulletin Soc. Géol. de France*, 3e Série, Tom. IX. p. 18, Paris, 1881, under the title of "Sur les Colonies dans les Roches Taconiques des Bords du Lac Champlain," with a detailed map of the borders of Lake Champlain between Georgia (Vermont), Chazy (New York), and Phillipsburgh (Canada). This region includes the typical localities of Georgia, Swanton, Highgate, Phillipsburgh, and Chazy, and comprehends the two States of Vermont and New York, and reaches into Canada. I give here only the tabular view or theoretic vertical section, with its *résumé* of explanation, referring those who wish to know the details to the original memoir.

VERTICAL SECTION [LAKE CHAMPLAIN] IN VERMONT, CANADA, AND NEW YORK, 10,140 FEET.

		Feet.	
Champlain Group, 1,050 feet.	Utica slate.	105	Thriarthrus Beckii, Graptolithus pristis.
	Trenton limestone.	360	Isotelus gigas, Illænus crassicauda, Calymene senaria, Ceraurus pleurexanthemus, Phacops, Trinucleus concentricus, etc., etc.
	Chazy limestone.	225	Isotelus canalis, Illænus, Asaphus, Maclurea magna, Scalites, Leptæna, Orthis, Atrypa, etc., etc.
	Calciferous sandrock.	360	Maclurea matutina, Ophileta, Orthoceras primigenium.
Upper Taconic, or the true Taconic System, 9,090 feet.	Potsdam sandstone.	300	Conocephalites Adamsi, C. vulcanus, C. minutus, C. verrucosus, Lingulepis minima, Obolella prima.
	Swanton slates, with lenticular masses of limestone.	2,400	No fossils, except *Graptolites* at Swanton Falls, at Point Lévis, Orleans Island, and River Ste. Anne. — Colonies of the second fauna at Highgate Springs, with Trinucleus, Calymene, Ampyx, Orthis, Rhynchonella, Lingula, etc.
	Phillipsburgh or Point Lévis Group, slates with lenticular masses of limestone.	3,000	Dikelocephalus, Olenus ? Bathyurus, Conocephalites, Monocephalus, Arionellus, Amphion, Cheirurus, Asaphus, Illænus, Lituites, Nautilus, Orthoceras, Maclurea, Murchisonia, Metoptoma, Ecculiomphalus, Camerella, Leptæna, Orthis, etc., etc. Prophetic types or forerunners of the second fauna at Phillipsburgh, Swanton, St. Albans Bay, and at Point Lévis.
	Georgia slates, with lenticular masses of limestone.	390	Olenellus Thompsoni, O. Vermontana, Dikelocephalus, Angelina, Conocephalites, Orthisina, Obolella, Camerella.
	St. Albans Group, slates with lenticular masses of limestone.	3,000	No fossils yet found *in situ.* The late Dr. G. M. Hall has signalized a fragment of *Bathyurus* ? at Highgate Falls; and a very indistinct Cephalopoda ? or a Pteropoda ? Also the late Rev. J. B. Perry has signalized an *Olenellus* ? near Franklin, and another behind St. Albans; and finally *Salterella pulchella* Billings in the Dove or Winooski marble of St. Albans, but it was not found *in situ* by Billings.

NOTE. — Plane of unconformity indicated by double and triple dividing lines.

The section given is of the beds immediately above the chlorite schists, the conglomerates, and the talcose slates which form the upper portion of the Lower Taconic.

Here are schists with lentils of magnesian limestone of three thousand metres, or about nine thousand feet, in thickness, extending from the top of the most westerly range of the Green Mountains to the borders of Lake Champlain. With the help of the rare fossils to be found in them, I have for convenience established four divisions in these beds, making an upward series as follows: —

At the base the *St. Albans Group*, three thousand feet thick, in which only one or two fossils of uncertain determination have yet been found, because the specimens have been lost or imperfectly studied. The one found near the town of St. Albans, and also at Franklin, may be an *Olenellus* or a *Paradoxides;* the other, found at Highgate Falls, may be a *Pygidium* of *Bathyurus;* also a fragment of *Cephalopoda?* or *Pteropoda?* Finally, *Salterella pulchella* was found in a fragment of Dove limestone near St. Albans, but not *in situ.*

2d. *Georgia slates*, or slates with *Olenellus;* they are about three hundred and ninety feet thick. Two small lenticular masses of blue and gray limestone, containing numerous fossils, are found at Swanton. At Parker's farm in Georgia a calcareous sandstone which contains iron geodes is found just above the *Olenellus* beds. The fossils are *Olenellus Thompsoni, Ol. Vermontana, Peltura holopyga, Angelina Hitchcocki, Dikelocephalus? Marcoui, Conocephalites Teucer, Obolella cingulata, Orthisina orientalis* and *festinata*, and *Camerella antiquata.*

3d. *Phillipsburgh or Point Lévis Group.*— Light black slates, containing now and then large lenticular masses of limestone. At Phillipsburgh the lenticular masses of limestone are very numerous and closely packed together, with only a sort of network of slates enclosing them, and forming, as it were, a frame or border. At Point Lévis the lenticular masses of limestone enclosed among the black slates are less numerous than at Phillipsburgh, and show a folding just at the chapel near the St. Joseph church. The thickness varies, but it cannot be less than three thousand feet. Fossils are numerous in some places, and at some special spots more or less limited. These are what Barrande has called *Colonies* of the second fauna enclosed in the strata of the primordial fauna, and I have named them *precursory centres* of creation, or centres in which forerunning species or generic types appear, that obtain their full development only during the following great period of the second fauna.

The fossils belong to the following genera and species: *Olenus? Logani; Dikelocephalus magnificus, Dik. planifrons, Dik. megalops, Dik. Missisquoi; Conocephalites Zenkeri; Menocephalus Sedgwicki, Men. Salteri; Bathyurus Saffordi, Bat. Cordai, Bat. bituberculatus,*

Bat. oblongus, *Bat. capax; Arionellus; Amphion Salteri; Cheirurus, Asaphus, Illænus; Lituites Farnsworthi, Lit. imperator; Orthoceras Marcoui, Orth. Missisquoi; Nautilus Pomponius; Maclurea matutina, Macl. ponderosa; Ecculiomphalus canadensis, Ecc. intortus, Ecc. spiralis; Metoptoma Niobe, Met. Orithya, Met. Hyrie, Met. Augusta; Murchisonia Vesta; Pleurotomaria postuma; Camerella calcifera; Leptæna sordida, Lep. decipiens; Orthis gemmicula, Ort. Tritonia; Ort. Electra, Ort. Hippolyte, Ort. Endosia;* and *Stricklandia? Arachne, Acrotreta, Obolella,* and *Lingula.*

4th. *Swanton slates* formed of black slates interstratified now and then with thin layers of a marly limestone; they are about twenty-five hundred feet thick. A few lenticular masses of limestone are enclosed, containing at Highgate Springs and some other places colonies of the second fauna, with *Trinucleus concentricus; Calymene Blumenbachii; Ampyx Halli; Orthis lynx; Rhynchonella increbescens; Stenopora fibrosa, Sten. Petropolitana; Orthoceras, Murchisonia, Columnaria,* and *Lingula.*

The *Graptolite beds* so numerous near Point Lévis and at Swanton Falls are in this group.

A dislocation of great magnitude occurred at the end of the deposit of the "Swanton slates."

5th. *Potsdam sandstone,* with its well-known rocks, lies in discordance of stratification over these different groups, and is found in many places where it has not been entirely destroyed and washed away by erosion. At Lake Champlain the Potsdam has been much eroded, and we have only the lowest part of it, about three hundred feet thick. The fossils are: *Conocephalites Adamsi, Con. Vulcanus, Con. minutus, Con. verrucosus; Lingulepis minima,* and *Obolella prima.*

Another dislocation occurred at the end of the deposit of the Potsdam, but not so important as the preceding one of the "Swanton slates."

CHAMPLAIN SERIES OR GROUP. — Just alongside, not more than half a mile distant from this typical region of the "Taconic system" of the eastern shore of Lake Champlain, are the peninsula of Alburgh, the Isle la Motte, and Chazy Landing, forming Emmons's group of Lake Champlain, with all its rocks and characteristic fossils, so totally distinct from the Taconic system. The Champlain group rests in discordant stratification of about 15° or 16° upon the Potsdam sandstone, very near the village of Chazy, and also at one mile to the west of the village.

The *Calciferous sandrock*, 360 feet thick, contains *Maclurea matutina, Turbo obscura,* and *Orthoceras primigenium.*

Then the *Chazy limestone*, 225 feet thick, containing a great many of the following fossils: *Illænus arcturus, Ill. crassicauda; Asaphus obtusus, As. marginalis; Isotelus canalis, Is. gigas; Ceraurus; Maclurea magna, Macl. striatus; Scalites angulatus; Pleurotomaria; Murchisonia; Bucania* or *Bellerophon; Orthoceras rectiannulatum, O. subarculatum, O. tenuiseptum, O. moniliforme; Atrypa; Orthis; Leptæna; Actynocrinus; Retepora; Chætetes*, etc.

Above we have the "Trenton," with the subdivision of the "Birdseye" and "Black River" limestone, 360 feet thick. The following are very common fossils: *Illænus crassicauda, Ill. latidorsata; Calymene multicosta, Cal. senaria; Isotelus gigas; Ceraurus; Phacops; Asaphus; Trinucleus concentricus; Orthoceras; Endoceras; Cyrtoceras; Bellerophon; Murchisonia; Pleurotomaria, Holopea; Modiolopsis; Tellynomia; Nucula; Atrypa; Spirifer; Orthis; Leptæna; Chætetes*, etc.

The "Utica slate," at Rouse's Point and Alburgh peninsula, with *Thriarthrus* (*Calymene*) *Beckii* and *Graptolithus pristis* most abundant, has a thickness of about 105 feet.

This section is the most complete that we have in America; even that of Nevada recently found at Eureka by Mr. Charles D. Walcott is less satisfactory for the Champlain series and the Potsdam sandstone. But there are two "gaps," to which I invite attention by trying to fill them without going far from Lake Champlain. These "gaps" are in the upper part of the Taconic, and are owing to the two "breaks" with discordance which took place before and after the deposit of the Potsdam sandstone.

But first I will give an extract from the last letter which I have received from the promoter of my researches on the Taconic system, my most regretted friend, Barrande.

"Prague, 10 Mars, 1882.

"Mon cher Monsieur Marcou.

". . . . Depuis que j'ai reçu, en Avril, 1881, votre beau mémoire *Sur les Colonies dans les Roches Taconiques des Bords du Lac Champlain*, il est resté sur ma table de travail. A diverses reprises je l'ai étudié pour bien apprécier vos observations et en rendre compte dans ma *Défense des Colonies* VI., en préparation.

"Il m'est agréable de reconnaitre, que vos nouveaux documents sont bien supérieurs à ceux que vous avez d'abord publiées et méritent toute considération. La multitude de mes occupations urgentes ne me permet pas aujourd'hui d'entrer dans la discussion des faits en question.

"Etant privé ici de beaucoup de ressources littéraires, je suis peu au courant de ce qui se passe en Amérique. J'ignorais qu'il fut de nouveau question de systême Taconique.

"Je serai charmé de voir les figures des fossiles (de Georgia) que Mr. Whitfield va publier d'après vos matériaux.

"J. Barrande."

III. Vertical and General Section of the Taconic System. — Infra-Primordial, Primordial, and Supra-Primordial Faunæ.

The dislocation of strata which occurred at the close of the deposit of the "Taconic slates," the last group of which I have called "Swanton slates," is the greatest as regards the breaking, squeezing, and local folding which has ever occurred in North America. The lateral pressure came from the east-east-south and met the *massifs* of *terra firma* of the Laurentine and the Adirondacks; all the strata were pressed together and taken between the force which pushed them from the east and the resistance from the west-west-north. They were first raised to a vertical position, and then overturned in fanlike shape.

Such are the origin and the form of that local folding of the earth's crust called the Green Mountain Chain of Vermont. The upper part of the "Swanton slates" came up against and spread over the crystalline rocks of the Adirondacks and the Laurentines, forming small local folds. The denudation took place immediately after; then the sea flowed over the upper part of the Taconic, extending even farther west, over the crystalline group of the Adirondacks, forming a gulf, of which Lake Champlain is the last witness, because it occupies a small part of it. This gulf deposited the "Potsdam sandstone," which covers a part of the Taconic. A new dislocation at the end of the Potsdam diminished the size of this gulf, reduced now to a sort of sound or fiord, in which the strata of the "Champlain series," or the true "Second fauna," were deposited, deposits which, added to the Potsdam, cover and hide entirely the upper part of the "Swanton slates."

But where the sea which deposited the Potsdam did not reach, as along the Laurentines from Three Rivers to Quebec, St. Anne, and lower down along the St. Lawrence River, all the "Swanton slates" must be found complete, leaning against the crystalline rocks. It is so at Quebec, Charlesbourg, Indian Lorette, Montmorency's fall, and

on the coast of St. Anne, where there is a group of Upper Taconic slates corresponding to the "Swanton slates," but of a much greater thickness, — at least 5,000 feet, instead of the 2,400 feet of the environs of Swanton.

In the town of Quebec even, at the Saut du Matelot, at the citadel, at Beauport, at Charlesbourg, and below Montmorency's fall, the schists have the same aspect and composition with the "Swanton slates," black, sometimes gray, even reddish; they contain some layers of blue limestone, lentils or kidneys of limestone, enclosed in the schists, and which at the Saut du Matelot resemble erratic limestone blocks shut into the black schists. They seem to be almost entirely destitute of fossils, except near the base, where are found the celebrated compound *Graptolites*.

In order to complete the general theoretic section of the Taconic, 2,500 feet, that is to say double the thickness of the "Swanton slates" as they are seen at Swanton, must be added.

The dislocation of the Potsdam resulted in the isolation and uncovering of a certain surface of these deposits of sandstone, conglomerate, dolomite, and limestone. This uncovered portion has been exposed to the great denudation which took place afterwards; the lowest parts alone remain; all the rest have been carried off. This explains why the Potsdam, or "Red Sandrock," in Vermont is only the lowest part of the formation. But in certain isolated cases portions have been less denuded, protected by divers obstacles, varying according to the localities: and here and there the Potsdam or "Red Sandrock" is quite thick.

One of these uninjured portions, preserved one might almost say miraculously, is near Saratoga, where it has been discovered by Mr. C. D. Walcott, who has described a part of the fossils he discovered, in the Thirty-second Annual Report of the New York State Cabinet. This upper part of the "Potsdam group" is formed of a "massive limestone," according to Walcott, containing a primordial fauna analogous to the Potsdam of Wisconsin. These are some of the forms: *Lingula, Platyceras, Metoptoma, Crepicephalus, Lonchocephalus, Dikelocephalus,* and *Ptychaspis*. (See Science, Vol. III. No. 52, p. 136.)

This upper limestone of the Potsdam covers the sandstone of Keeseville (Au Sable Chams), and the red sandstone of Highgate (Church farm).

This important discovery in this typical region of the Taconic completes the series of all the beds of this great and important system. The objection of the non-existence of this limestone formation under

the strata of the Champlain series at the village of Chazy, and at Potsdam itself, is explained in two ways. First, there is sufficient distance between Saratoga and Chazy for a local deposit of limestone to be made in one place and not in the other. But it is still more important to observe that at Chazy and at Potsdam the Potsdam rock has formed a beach during the whole time of the Champlain deposits. The character of this beach has been preserved in so striking a manner, that one would think it had been abandoned by the sea but a few years, even in our own day; it was greatly eroded and all its upper beds were destroyed shortly after the dislocation, and before the first deposits of the "Calciferous" and of "Chazy limestone."

It is almost certain that this important discovery by Mr. Walcott will not be the only one, and that this upper part of the Potsdam will be found along the line of the Taconic, from Lake Champlain to Alabama. It has been pointed out and described long since in Wisconsin and Minnesota.

If we complete the theoretic vertical section already given in 1881 for the Lake Champlain region, and taking account of the discovery of the zone of *Paradoxides* on the borders of the Atlantic, we have the following section.

TABULAR VIEW OF THE TACONIC SYSTEM IN EASTERN NORTH AMERICA.

			Feet.		
Potsdam Group, 400 feet.		Saratoga limestone.	100	Dikelocephalus, Lonchocephalus, Crepicephalus, Lingula.	Supra-Primordial fauna.
		Red Sandrock of Vermont and Keeseville.	300	Conocephalites Adamsi, C. minutus, C. vulcanus, Lingulepis, Obolella prima.	
Swanton Slates, 5,000 feet. Zone of the Colonies of the second fauna.		Upper Swanton slates or Quebec group of the city and citadel of Quebec, Charlesbourg, and Montmorency's fall.	2,600	Almost destitute of fossils.	
		Lower Swanton slates or slates between Swanton's fall and the shores of Lake Champlain.	2,400	Graptolites at Swanton's fall, and at the ferry road of Point Lévis, River St. Anne, and Gros Maule (Canada). Colonies of the second fauna at Highgate Spring, with Trinucleus, Calymene, Ampyx, Orthis, Rhynchonella, etc.	
Zone of the prophetic types or precursors of the second fauna.		Phillipsburgh or Point Lévis Group.	3,000	Dikelocephalus, Olenus? Conocephalites, Arionellus, Bathyurus, Menocephalus, Amphion, Cheirurus, Asaphus, Illænus, Lituites, Nautilus, Orthoceras, Maclurea, Murchisonia, Metoptoma, Ecculiomphalus, Camerella, Leptæna, Orthis, etc.	
		Georgia slates, or Olenellus Zone.	400	Olenellus Thompsoni, Ol. Vermontana, Dikelocephalus? Angelina, Conocephalites, Orthisina, Camerella, Obolella.	Primordial fauna.
St. Albans Group, 5,500 feet.	Paradoxides Zone.	St. John or Acadian Group (New Brunswick).	2,700	Paradoxides Acadicus, Par. Eteminicus, Par. lamellatus; Conocephalites (14 species), Agnostus (2 species), Microdiscus, Elliptocephalus, Lingula, Obolella, Orthis, Discina, Eocystites, Salterella, Hyolithes, and Orthoceras.	
		Argillites of Braintree, Mass., and St. Mary's Bay, Newfoundland.	300	Paradoxides Harlani, Par. Bennettii, Par. decoris, Par. tenellus; Arionellus, Agraulos, Anapolenus, Obolella miser.	
		Eophyton sandstone of Great Bell Island (Newfoundland).	1,500	Eophyton Linnæanum, E. Jukesi, Arthraria, Lingula, Lingulella, Cruziana, Iphidea, Palæophicus.	Infra-Prim. fauna.
		Aspidella and Arenicolites slates of St. John's, Newfoundland.	1,000	Aspidella Terranovica, Stenotheca, Scenella, Arenicolites spiralis.	

Greenish and bluish slates, quartzites, and conglomerates, trappean or diabase beds, and volcanic ash ?

Let us remember that the St. Albans Group, even at St. Albans or in the neighborhood, has as yet brought nothing certain to palæontology, and that there are only doubtful indications which I have placed on the "Lake Champlain section" as a halting-point or query. Without doubt fossils are very rare, but let us hope that some day the cutting of roads and opening of quarries will lead to their discovery, especially in the zone which should represent there the *Paradoxides beds.*

In the eastern part of the great masses of crystalline rocks in New England and Newfoundland, the fossils of the Primordial fauna have been found, indicating always by their forms, and their stratigraphic positions in close proximity to the crystalline rocks, that they come from the lowest parts of the fossiliferous rocks of the "Taconic system."

If these localities are classed according to their faunæ, the only possible way, considering the absence of superposition and the great distance which separates them, they may be thus described in a descending series.

St. John Group, or Acadian Group. — In the town of St. John, New Brunswick, and also very near its suburb Portland, in the slates upon which these two towns are built, the Rev. C. R. Matthews found in 1862 fragments of trilobites, which have been since carefully studied and published by Mr. G. F. Matthews, under the title of "Illustrations of the Fauna of the St. John Group," in the Transactions of the Royal Society of Canada, 4to, Section IV., 1882.

The first discoveries have been much added to by several observers, and as the fossils have been gradually collected they have been published, first by C. F. Hart in the "Report of the Geological Survey of New Brunswick" (1865) carried on under Prof. L. W. Bailey, and in the "Acadian Geology" (1868) of Principal Dawson, then by Billings and Matthews. The following is the list of fossils.

Paradoxides, 7 species or varieties; *Conocephalites*, 14 species; *Agnostus*, 2 species; *Microdiscus*, 1 species; *Elliptocephalus*, 1 species; *Lingula, Obolella, Orthis, Discina, Eocystites, Salterella, Hyolithes*, and *Orthoceras.*

It is pre-eminently the Primordial fauna of Barrande, "Zone des Paradoxides," with the certain apparition of a Cephalopod well recognized by Prof. A. Hyatt. The thickness of the beds at Portland and St. John is about three thousand feet, composed mostly of slaty shales, flags, and quartzites, with red sandy shales and conglomerates at the base.

The fossils are found at two hundred feet from the base, and are

confined exclusively to the slates at different levels, in a height of twenty-seven hundred feet.

This "Group of St. John," also called "Acadian Group," must be regarded as the upper part of the St. Albans Group, for the fossils indicate a lower level than the fauna of the "Georgia slates" with *Olenellus;* but they are not far from these; the Brachiopods resemble them very much, and the Trilobites have affinities with them, while they have a *facies* of greater antiquity, because of the *Parodoxides* and a considerable number of *Conocephalites.*

As to the stratigraphy and the fossils, Mr. Matthews says: "No trace of a fossil could be seen in the black slate. But scattered at intervals through some of the bands of this slate were hard, compact masses of rock, which, when broken, were found to be packed with fossils. The spherical and elliptical masses, which varied in size from about a yard in diameter to nodules of one inch across, had the appearance of imbedded boulders, but the fossils in them were always parallel to the stratification, and similar fossils were subsequently found in irregular beds and lenticular bands of hard rocks. In the boulder-like masses there were numerous layers loaded with organic remains, which extended without diminution in the number of the fossils to the very edge of the block, where they suddenly disappeared, and not a trace of them could be found in the adjoining slate rock." *

There is a repetition of what I have pointed out on the borders of Lake Champlain and at Point Lévis, only the lenticular masses are of smaller dimensions, and recall those of Scandinavia.

Braintree, near Boston, Massachusetts. — Ten miles south from Boston, in direct contact with the syenitic granite of Quincy, are several quarries of argillites, two of which contain two trilobites rarely to be found; — one very large, the head or cephalic shield reaching even a foot in width, the *Paradoxides Harlani* Green; the other very small, almost minute, *Arionellus quadrangularis* Whitf. Beside these, a Cephalopod perhaps and a marine plant. These fossils are only found within a space of a few square yards; much narrower limits than the fauna of St. John, New Brunswick, or any of the localities of the fossiliferous Taconic on the borders of Lake Champlain.

Braintree evidently belongs to the "Zone of Paradoxides," in the lower part of this zone, and I place it, until the contrary is proved, below the "Acadian Group" of St. John, and about the middle of the "St. Albans Group."

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* Illustrations of the Fauna of the St. John Group, p. 90.

Peninsula of Avalon, Newfoundland. — The south-southeastern part of Newfoundland, between Cape Race, the Bay of Placentia, and Trinity Bay, is occupied by some outcrops of syenite and gneiss, which cut into and cross the argillites, slates, quartzites, and conglomerates.

The following fossils have been found at Branch, in St. Mary's Bay and at Chapel Arm, Trinity Bay, in an argillite analogous to that of Braintree, and also directly in contact with the syenitic granite: *Paradoxides Bennettii* Salt., *Parad. decoris* and *Parad. tenellus* Bill., *Agraulos socialis* and *Agr. affinis* Bill., *Solenopleura communis* Bill., *Anapolenus venustus* Bill., and *Obolella? miser* Bill.

The argillite of Newfoundland covers a much larger surface than that of Braintree; the *Paradoxides Bennettii* is almost as large as *Par. Harlani.* This small trilobitic fauna not only belongs also to the lower part of the "Paradoxides zone," but is very likely contemporaneous with that of Braintree. In the theoretic section these two faunæ are placed together in the middle of the St. Albans group and below the Acadian Group of St. John, New Brunswick.

In Conception Bay, to the east of Branch and Chapel Arm, at Great Bell Island, and at Topsail Head and Brigus, in sandstone conglomerate and argillite, the following fossils have been found: *Eophyton Linnæanum* Torell, *Eoph. Jukesi* Bill., *Arthraria antiquata* Bill., *Lingula Murrayi* Bill., *Lingulella spissa* Bill., and *Lingulella affinis* Bill., *Iphidea bella* Bill., *Cruziana similis* Bill., *Paleophicus,* and two or three new species of *Lingula.*

Lastly, in the argillite of the town of St. John's have been found *Aspidella Terranovica* Bill., *Stenotheca pauper* Bill., *Scenella reticulata* Bill., and *Arenicolites spiralis* Bill.*

The absence of trilobites and the presence of such forms as *Eophyton* and *Arenicolites* found in Sweden below the Paradoxides zone, and other new or very ancient and very enduring forms, such as *Lingula* and *Lingulella,* seem to indicate a greater age for this fauna than that of the Paradoxides zone; that it corresponds to the divisions of "*Eophyton* and *fucoid* sandstones" of Sweden, of Linnarson; and that we have there the oldest fossils, until now, found in the eastern region of North America.

This fauna, certainly more ancient than Barrande's typical Primordial fauna of Bohemia, and which I place at the lower part of the

* See Geological Survey of Newfoundland, Report of Progress for the Year 1881, p. 13, and Appendix (St. John's, 1882).

St. Albans Group, is in reality *Ante-Primordial*, or more exactly *Infra-Primordial*, and in future I will designate it by this name. I place in it, temporarily at least, the two fossils *Straparollina remota* and *Hyolithes excellens* Bill., found at Smith's Sound, in Trinity Bay, as well as *Agraulos strenuus* Bill., of Brigus and Topsail Head, Conception Bay.

I do not now refer to the regions of Newfoundland near the Straits of Belle Isle, where the Georgia Group with *Olenellus Thompsoni*, and the Group of Phillipsburgh and Point Lévis, have been found; nor to the determination of certain beds as being of the age of the Potsdam and of the Calciferous. The existence of the true Potsdam and the Calciferous is very doubtful, as no fossils identical with those of the typical localities of the State of New York have been found.

Infra-Primordial, Primordial, and Supra-Primordial Faunæ.—I have called the most ancient fossils of Newfoundland *Infra-Primordial*, in order to distinguish them from the true *Primordial*, as Barrande has characterized it in Bohemia, and which is represented in America by the zones with *Paradoxides* and *Olenellus*. But we have also in America a fauna which has no representative in Bohemia, where the overflow of porphyry put an insurmountable obstacle to marine existence. This fauna is found at Hof in Bavaria, at Vestfosen near Christiania in Norway, and elsewhere in Europe; declared by Barrande primordial at Hof, while Linnarson looks upon it as the second fauna; and Brögger calls it by the name of *Asaphus Etage* in Norway. It is formed of Primordial types united with types whose great development takes place in the second fauna, properly so called, and for these reasons I give it the name of *Supra-Primordial*.

So we have in America and in Scandinavia, and very probably elsewhere, three Taconic faunæ. 1st. The *Supra-Primordial*, which at Lake Champlain includes colonies of the second fauna, and is terminated by the "Potsdam sandstone," including the "Saratoga limestone," with primordial fossils discovered by Walcott. 2d. The true *Primordial* fauna, including the zones with *Olenellus* of the Georgia schists, that with *Paradoxides* of the St. John or Acadian Group, and the argillites of Braintree and St. Mary and Trinity Bays. 3d. The lowest Primordial fauna, or *Infra-Primordial*, still more sporadic, with more simple and primitive forms, of Conception Bay, Smith's Sound, and St. John's harbor, Newfoundland.

IV.—The Taconic of Eureka (Nevada) and of the Grand Cañon of the Colorado River (Arizona).

The important and unexpected discovery of the uppermost part of the Potsdam at Saratoga with the same fauna as the Upper Potsdam of Wisconsin, St. Croix River, Lake Pepin, and Trampaleau, is not the only one that American stratigraphy owes to Mr. C. D. Walcott. This *savant*, whose studies on the manducatory and ambulatory appendages of the trilobites are justly celebrated, has in the last three years, 1881, 1882, and 1883, made other discoveries of great value in the regions of the Grand Cañon, Arizona, and the Great Basin, Nevada. Mr. Walcott gives the following general and ideal section of the Taconic strata of the Grand Cañon of the Colorado River.

GENERAL AND IDEAL SECTION OF THE TACONIC ROCKS OF THE GRAND CAÑON (COLORADO).

		Feet.			
Tonto Group, 1000 feet.	Upper sandstone, shales, and limestone.	700	Dikelocephalus, Conocephalites, Crepicephalus, Iphidea, Lingulepis, Cruziana.	Saratoga and Wisconsin division.	Potsdam Sandstone Group.
	Coarse sandstone.	300	No fossils.	Red Sandrock of Vermont.	
Pre-Tonto Group, 10,000 feet.	Chuar Group.	5,000	Only three fossils have been found yet: first, a small Discinoid shell; second, a pteropod allied to *Hyolithes triangularis*; and third, an obscure *Stromatopora*.		Infra-Primordial fauna, or lower part of the St. Albans Group.
	Grand Cañon Group.	5,000	No fossils.		

Crystalline rocks.

Note.—Plane of unconformity indicated by double dividing line. No trace of the Primordial fauna, and of the Supra-Primordial fauna, except in the upper part, or Saratoga and Wisconsin subdivision.

The upper part is formed of sandstone, shales, and limestone, 1,000 feet thick. Major J. W. Powell has called it the "Tonto Group." *Tonto* means *stupid;* it is the name the Mexicans give to the Indians of that region. The fossils are found in the middle and upper part of the group, and belong to the genera *Dikelocephalus*, *Crepicephalus*, *Conocephalites*, *Iphidea*, *Lingulepis*, and *Cruziana*. They indicate the Upper Potsdam of Wisconsin, and of Saratoga County, New York. The fauna of the Lower Potsdam of Keeseville, New York, and of Highgate, Vermont, has not been found in the Grand Cañon.

There is a slight line of unconformity between the upper part of the Potsdam or "Tonto Group" and the Devonian, which rests directly upon the Taconic.

The Potsdam rests unconformably on 10,000 feet at least of strata called "Pre-Tonto, or Chuar and Grand Cañon Groups." The first 5,000 feet constitute the "Chuar Group," and are formed of sandstone, argillaceous shales, and limestone, resembling in texture and composition the Trenton limestone and Utica slate.

After very careful researches, prolonged for two months and a half, Mr. Walcott was only able to collect three species of fossils, — a small Discinoid shell, a Pteropod allied to *Hyolithes triangularis*, and an obscure *Stromatopora*. Evidently fossils are very rare, and those found indicate an Infra-Primordial fauna below the zones with trilobites, and recalling the fauna of Conception Bay and Smith's Sound, Newfoundland.

In the 5,000 feet of the "Grand Cañon Group" formed of sandstone interposed between "flows of greenstone-lava beds," as Walcott calls them, no fossils have been found; and one reaches, at last, quartzites crossed by veins of granite.

To resume. This section of the Grand Cañon only shows the base and the summit, that is, the first and last group of the Taconic system. All the middle parts are wanting. As there has been a very marked break, before the deposit of the Potsdam or "Tonto group," we may think that the upper portions have been destroyed by erosions, or are thrown to the right or left of the very narrow region of the Grand Cañon of the Colorado River.

A little farther north, in the Eureka district, and even already in the ranges of highlands in Eastern Nevada, and of Oquirrh in Utah, the middle portions of the Taconic system have a superb development of beds and of fossils, which fully completes the Taconic in the western regions of North America.

Eureka. — At Pioche City, the able geologist, Mr. E. E. Howell, has found the zone with *Olenelli*, or "Georgia Group," well characterized; and Mr. S. F. Emmons has recognized this zone with *Olenelli* a little farther north in the Oquirrh Mountains. Longer and more detailed researches have been made in the mining district of Eureka by Messrs. Arnold Hague and C. D. Walcott, and I will give the section of Eureka recently published in the "Abstract of Report on the Geology of the Eureka District, Nevada," by Arnold Hague (Third Annual Report of the United States Geological Survey, 1881-82, p. 253, Washington, 1884). I give here less than half this section as having relation to the Taconic.

Lower Part of the Eureka Section, Nevada, 12,700 *feet.*				*Eastern N. America.*	
Cambrian or Champlain.	Lone Mountain limestone.	Feet. 1,800	Isotelus gigas, Trinucleus concentricus, Illænus, Leptæna, Ceraurus, Orthoceras, Cytoceras, Chætetes.	Champlain Group or Cambrian.	Second fauna.
*	Eureka quartzite.	500	No fossils yet found.	Potsdam sandstone?	Supra-Primordial fauna.
	Pogonip limestone.	2,700	Blue limestone with distinctly bedded structure; containing colonies of the second fauna, mingled with and among primordial fossils, Dikelocephalus! Crepicephalus Gallatinensis!!! Agnostus, Acrotreta, Obolella, Lingula manticula!! Lingulepis, Illænus, Bathyurus, Asaphus, Amphion, Cystolites, Orthoceras, Maclurea, Orthis, Chætetes, and a Graptolites.	Swanton slates.	
	Hamburg shale.	350	Dikelocephalus! Conocephalites, Crepicephalus Gallatinensis!!! Agnostus, Kutorgina, Obolella, Lingula manticula!! Lingulepis.	Phillipsburgh or Point Lévis Group.	
Taconic System, 10,900 feet.	Hamburg limestone.	1,200	Dikelocephalus (2)! Conocephalites (4), Crepicephalus Gallatinensis!!! and 5 others, Chariocephalus, Oxygia, Agnostus (4), Hyolithes, Kutorgina, Acrotreta, Iphidea, Lingula manticula!! Lingulepis.		
	Secret Cañon shale.	1,600	No fossils in shale; a few imperfect fragments in calcareous beds.		
	Prospect Mountain limestone.	3,050	300 ft. of shaly beds with fossils: Dikelocephalus! Conocephalites, Crepicephalus Gallatinensis!!! Agnostus, Lingula manticula!! Obolella.		
			2,000 ft. of Magnesian limestone. No fossils.		
			Conocephalites Prospectensis, Dikelocephalus! Agnostus, Scenella.		
			500 ft. of Magnesian limestone and shales in lenticular or wedge-shaped bodies. No fossils.		
			100 ft. of red arenaceous shale or Olenellus shales. Olenellus Barrandi, O. Iddingsi, O. abnormis, Conocephalites, Acrotreta.	Georgia slates or Olenellus zone.	Primordial fauna.
	Prospect Mountain quartzite.	1,500	No fossils.	St. Albans Group.	No trace of the Infra-Primordial fauna.
Granite below the quartzite.					

NOTE. — Plane of unconformity indicated by double dividing line.

* Very likely a break or unconformity of some kind exists here.

A very thick solid mass of conglomerates, micaceous shales, and specially quartzite, of at least 1,500 feet, without fossils, rests upon the granite which is visible at but one point; this group is called "Prospect Mountain quartzite." (All the names of groups given by Messrs. Walcott and Hague are names peculiar to the region of Nevada and Eureka.) This group without fossils corresponds stratigraphically to the "St. Albans Group."

Directly above is the "Prospect Mountain limestone," which begins by a bed, 100 feet thick, of shales with *Olenelli*. The authors have united and confounded this very important horizon of the zone of *Olenelli* with a great mass of limestone, from which it is doubly distinct, — first by its lithology, and secondly by its palæontology. I have shown this on the section by a line. In these shales there are three species of *Olenellus*, a *Conocephalites*, and a brachiopod *Acrotreta*. This little fauna corresponds so well with that of Georgia, that it is needless to insist on the affinities which connect them. So the zone with *Olenelli*, or "Georgia slates," are strongly marked in Nevada. Above are 500 feet of bluish limestone without fossils. Then we come to a horizon of fossils belonging to the genera *Dikelocephalus*, *Conocephalites*, and *Agnostus*. Higher up is an enormous mass of 2,000 feet of metamorphosed and broken up limestone without fossils; and the last 300 feet, at the upper part, containing quite a large number of fossils belonging to the genera *Dikelocephalus*, *Crepicephalus*, *Conocephalites*, *Oxygia*, *Agnostus*, *Orthis*, *Lingula*, *Obolella*, etc. On the whole, a fauna resembling that of Point Lévis in Canada, and already Supra-Primordial.

Then comes a mass of slates 1,600 feet thick, without fossils, or having only imperfect traces of fossils badly preserved, called "Secret Cañon shale."

At the top of this group are the "Hamburg limestones," 1,200 feet thick, with numerous fossils, belonging to the genera *Dikelocephalus*, *Crepicephalus*, *Conocephalites*, *Oxygia*, *Agnostus*, *Hyolithes*, *Kutorgina*, *Iphidea*, *Lingula*, *Lingulepis*, etc., — a fauna having all the characters of the Supra-Primordial.

Then come 350 feet of the "Hamburg shale," with a fauna almost identical with the preceding one in genera and species; the whole is really but one group, the "Hamburg Group," which, added to the "Secret Cañon shale," and to the "Prospect Mountain limestone," from which we must take 100 feet at the base where are the "Georgia slates" with *Olenelli*, represents in Nevada the "Phillipsburgh and Point Lévis Group" of Vermont and Canada. At Eureka

this group does not seem to show the types prophetic of the second fauna, so remarkable at Phillipsburgh.

For Messrs. Walcott and Hague, the Cambrian ends with the "Hamburg shale," without a break in the stratification and without a well-marked palæontologic horizon, since the species pass into the higher group which they call "Pogonip limestone." These *savants* have been influenced by the apparition of forms of the second fauna, and place themselves at a point of view entirely palæontologic, although quite open to discussion, even palæontologically. They have drawn there a strong line of separation between two geologic ages, which they call "Cambrian" and "Silurian."

The "Pogonip limestone," 2,700 feet thick, gradually passes into the "Hamburg shale" in concordant stratification, and contains a fine fauna, a decided mingling of species of primordial and second fauna forms, exactly the same as at Hof in Bavaria, and at Christiania, Norway. Mr. Walcott gives a list of sixteen species which he recognizes as common here and in the beds beneath, which he calls "Cambrian." They are *Dikelocephalus*, *Crepicephalus*, *Arethusina*, *Agnostus*, *Acrotreta*, *Obolella*, *Lingula*, and *Lingulepis*.

Towards the middle of the "Pogonic group" are found *Bathyurus*, *Amphion*, *Asaphus*, *Illænus*, *Maclurea*, *Orthoceras*, *Orthis*, etc. All these forms exist at Point Lévis, Phillipsburgh, and Highgate Springs; and at Eureka and in Nevada we have the same mixture and the same associations as in Vermont and Canada.

One single Graptolites has been found in Nevada, and it is in the "Pogonip group."

By its position above the beds with *Dikelocephalus* of the "Hamburg and Prospect Mountain Groups," and its mixed fauna, it is evident that here are the Colonies of the second fauna in the primordial fauna, as in the "Swanton slates" of Lake Champlain; and I do not hesitate to consider the "Pogonic limestone" as representing in Nevada the "Swanton slates."

Above we have the "Eureka quartzite," 500 feet thick, in which, unhappily, as yet no fossils have been found; but we must remember, that many years had passed before the discovery of the small *Conocephalites Adamsi* and *C. minutus* at Highgate and at Keeseville, and that we may hope for a like success at Eureka. In position and lithology the Eureka quartzite recalls the "Red Sandrock" of Vermont and the "Potsdam" of Keeseville, Chazy, and Potsdam. Further, although Messrs. Hague and Walcott have not recognized a discordance between this group and the "Pogonip," the excellent Geological

Map of the Eureka District accompanying the memoir of Arnold Hague shows the "Eureka quartzite" either seeming to overlap, or lying in direct contact with, all the different groups of Primordial, except the "Secret Cañon shale," which can only be explained by a transgressive discordance or a different geographical distribution of the level of the sea. It is probable that the great break of the Green Mountains, the most important as breaking and dislocation of strata that has ever happened in North America, was felt in its effects in this Nevadian fiord of the Upper Taconic by a slight change in the level of the sea, sufficient to produce a geographical distribution special and peculiar to the deposits of sand which form the "Eureka quartzite."

In order to show the numerous points of resemblance and the multiple relations existing between the "Eureka quartzite" and the "Red Sandrocks" or "Potsdam sandstone" of Vermont, New York, and the Grand Cañon of Arizona, I will add that there has been at Eureka a break between the quartzite and the following formation, the "Lone Mountain limestone." An unconformity exists between the two formations, and a denudation or erosion has destroyed the upper part of the "Eureka quartzite." As we know now that it is the upper part of the Potsdam which contain fossils, the lower having furnished in all America but six or eight species, we can understand why no fossils have yet been met with in the quartzites occupying the place of the "Potsdam sandstone" at Eureka.

The "Taconic System" in Nevada is finished with the "Eureka quartzite." The second fauna is above, analogous to that of the "Champlain division" of Emmons, and the "Lone Mountain limestone," from 1,800 to 2,000 feet thick, represents the true "Cambrian," from the "Calciferous," "Chazy," and "Trenton," even to the "Utica" and "Lorrain shales." It is nearly double the thickness of the typical series of New York.

Messrs. Walcott and Hague make one system only of the five lower divisions, "Prospect Mountain quartzite and limestone." "Secret Cañon shale," and "Hamburg limestone and shale," they call "Cambrian." Then uniting the "Pogonip limestone" with the "Eureka quartzite" and the "Lone Mountain limestone," they have made a second system of 5,000 feet, which they call "Silurian." It is an entirely palæontological classification, which follows only uniformist preconceived opinions. It pays no attention to discordances of stratification, nor to Primordial forms, especially the Primordial species, some of which are found from "Prospect Mountain" to "Pogonip limestone," such as *Lingula manticula* and *Crepicephalus Galati-*

nensis. If the beds are classed after the principal genus found in them, as has been done in Scandinavia, where the divisions or groups are called "zone of *Paradoxides*," "zone of *Olenelli*," "zone of *Asaphus*," &c., there are at Eureka two well-marked zones, — the "zone of *Olenelli*" at the base of the "Prospect limestone," and the "zone of *Dikelocephali*, reaching even the "Eureka quartzite." The genus *Dikelocephalvs* is one of the most constant and the most universal in the Supra-Primordial of North America.

Thus it will be seen that the "Taconic System" is perfectly developed, as well at the Grand Cañon as at Eureka; and that all the horizons, or palæontologic zones, have been found there of the typical Atlantic regions of the Taconic in America, as I have shown them in the general and theoretic section. One alone has not been recognized, — the "zone with *Paradoxides*" of Braintree, St. Mary's Bay, and St. John, New Brunswick. But the Infra-Primordial is well represented in the "Chuar group" of the Grand Cañon; the Primordial, in the zone with *Olenelli* at Eureka, Pioche, and Oquirrh; and the Supra-Primordial in the zone with *Dikelocephali*.

These divisions terminate, as at Lake Champlain and Saratoga, with a covering in discordant stratification of a mass of sandstone identical with the "Red Sandrock" or "Potsdam sandstone," which Mr. Walcott calls "Tonto Group" and "Eureka quartzite."

The classification here given only differs in the groupings and denomination of the systems. I will give my reasons later for not using the terms "Cambrian" and "Silurian" as they are used by Messrs. Walcott and Hague; but the divergence of opinion on the general classification and the use of names does not at all diminish the value of the remarkable observations in the region of the Great Basin and the Grand Cañon made by these *savants*. Their researches and discoveries are of great importance, and their value cannot be too highly appreciated.

V. Geographical Distribution of the Taconic. — Norway.

It is not necessary to review all the localities and regions of America where the Taconic System and the Primordial fauna have been discovered; it is sufficient to say that America has far more than the Old World of depositions already described, and of variety in the fossils collected; and it appears from what we know, that life was manifested in the New World under forms which have preceded the apparition of similar ones in Europe. We may say with confidence that from Newfoundland and Belle Isle to Eureka and the Grand

Cañon of the Colorado River towards the west, and to Alabama and Texas on the south, there are almost continuous lines of the outcropping of the Taconic System; and that the only point in the southern hemisphere where the Primordial fauna has been yet certainly found is in the Argentine Republic at Salta and Jujuy.

I must make a reservation as to the "Lake Superior sandstone" and "Keweenawan series" of eruptive rocks. No proof whatever, palæontological,* stratigraphical, or lithological, has been given of their being of the age of the "Tonto Group" (Potsdam sandstone), or of the "Grand Cañon and Chuar Series" of the Colorado River; and their synchronism is merely a speculative supposition. The identification of those sandstones with the Potsdam of New York, which was based on the discovery of a great quantity of *Lingula prima* at Tequamenon Bay, has long been given up. They came from a small boulder of the glacial deposits. Dr. C. Rominger says, "There is no record of any instance in which recognizable fossils were found *in situ* in the Lake Superior sandstone."† Dr. R. V. Irving says, "The horizontal sandstone of the south shore of Lake Superior belongs unquestionably to this formation (Potsdam sandstone), though it is a matter of doubt whether the two sandstones do or ever did connect."‡

All the eruptive rocks, melaphyrs, and a part of the diabases and porphyries containing native copper and zeolites are similar and identical with the same rocks in Connecticut, Pennsylvania, and Nova Scotia on this continent; and with the rocks containing copper in Thuringia, where they belong to the Kupferschiefer and Rothliegende of the Dyas (Permian). If lithology has a meaning with regard to the age of rocks, the copper-bearing rocks of Lake Superior are Dyasic, while the Lake Superior sandstone of Sault Ste. Marie, Gros Cap, La Pointe, and Bois Brulé River belongs to the Bunter Sandstein of the Trias.

As to the existence of the Taconic System in the Lake Superior region, it is very possible that the slates of Kakabekå Falls, and some slates, conglomerates, diabases, and gabbro found on the edge and even in the interior part of the crystalline rocks forming the centre

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* Several specimens having a decided *Orthoceratites* form have been found in the melaphyr and diabase of Point Keweenaw since 1848, a fact similar to the discovery of undoubted pieces of *Orthoceratites* in the diabase of Bohemia, and this goes far to confirm the Post-Silurian age of the copper-bearing rocks of Lake Superior.

† Geol. Surv. of Michigan, Vol. I. Part III. p. 80, 1873.

‡ The Mineral Resources of Wisconsin, p. 11, 1880.

of the highlands between Lake Superior, the Upper Mississippi, and Green Bay, belong to it, but as yet palæontological proofs are entirely wanting. Mr. A. R. C. Selwyn considers the columnar trap or diabase which forms the summit of Thunder Cape, Pie Island, and McKay's Mountain as contemporary with the black slaty shales of Kakabeka Falls, called "Animikie Group"; and not belonging to the "crowning overflow" of the melaphyr copper-bearing rocks. My own observations, made in 1848, coincide with this view; and I am led to think that the diabases of this region, northwest of the lake, are identical with those of Etchemin and Chaudière Rivers near Quebec, and of Bel Œil, Montarville, and Rougemont near the Richelieu River; and that the black slates of Kakabeka Falls belong to the "Swanton slates" of the Upper Taconic.

In Australia, notwithstanding the discovery of compound *Graptolites* in the province of Victoria, one group of fossils alone, and of so low an order, will not suffice us to decide upon the positive existence of the Taconic System, although it appears very probable.

In Africa no Primordial fauna has as yet been found.

In Asia, China only has furnished certain proof, at Liau-Tang, that the Taconic System is well developed.

In Europe, Barrande has had the honor of first establishing, and then pointing out, the Primordial fauna and the Taconic System in Bohemia, in Great Britain, in France, in the Iberian peninsula, in Sardinia, in Bavaria, and in Scandinavia.

The development of the strata of the Taconic System, and the forms and number of fossils in the classic countries of the Primordial, England, Bohemia, and Scandinavia, are inferior to the American series on both these points.

In Bohemia, according to Barrande, there was an irruption of porphyry, which prevented any marine life, and placed a complete barrier between the primordial and the second fauna. We may say, further, that these porphyries arrested the development of the primordial fauna, which presents in Bohemia only the lower portion, or "*Paradoxides* zone," of the Primordial properly so called, without any trace of the Infra- or of the Supra-Primordial faunæ. There we have only the zone with *Paradoxides* represented in America by Braintree, near Boston; St. Mary, near St. John's, Newfoundland; and the environs of St. John, New Brunswick.

The result of this interruption of life in Bohemia between the "*Paradoxides* zone" and the second fauna, is the incompleteness of the palæontologic series, and an absolute limit to the passage of any

species; and hardly any genera exist between the primordial groups and those of the second fauna. In a word, the record of the palæontologic register of Bohemia is incomplete. It is evident that, although the development of life was interrupted in Bohemia, it must have continued elsewhere; for, once begun, nothing short of the destruction of the earth could stop the evolution of living forms. Thus, a fauna was shortly found not far from Bohemia, composed of the true primordial types, with a mixture of forms whose extended development was only reached during the existence of the second fauna. Dr. Gümbel, director of the geological survey at Hof, in Bavaria, in 1862 found this intermediate fauna. Studied by Barrande in 1863, this *savant* recognized that, beside the primordial types, such as *Olenus* and *Conocephalites*, there are forms of the second fauna of Bohemia, as *Asaphus*, *Calymene*, and *Cheirurus*, but belonging to different species. Then, supporting himself on the absence of the *Paradoxides* type at Hof, he concludes "that the fauna of Hof is posterior to the primordial fauna of Bohemia." And he adds: "Thus the fauna of Hof appears to correspond to an intermediary epoch between our primordial fauna and that of the first phase of our second fauna. This intermediary age is not represented by any fauna in our basin [Bohemia]. But it is natural to conceive that it corresponds to the time during which the masses of porphyry overflowed into the Silurian sea of Bohemia, which are intercalated between the strata enclosing our first two faunæ. In effect, the plutonic phenomena which introduced these rocks into our formations must have made the sea of these regions uninhabitable to the contemporary faunæ."* However, the deposit at Hof is isolated, and in direct contact with the Devonian.

In Scandinavia the strata of the lower palæozoic rocks are of much less thickness than in Bohemia, in Great Britain, and especially in America. They average only about one thousand feet for the whole series of the primordial and second fauna, instead of the ten and twenty thousand feet of the English and American series. Further, these strata have suffered numerous dislocations and breaks, which have parcelled them out in small groups, on divers points, at some distance from each other. And to add still more to these difficulties, great denudations, carrying after them enormous quantities of materials transported by the great glaciers of the glacial epoch, have destroyed or covered up all the strata, leaving merely some outcroppings here and there, very difficult to class and to connect certainly with each other.

* Faune Silurienne des Environs de Hof en Bavière, pp. 56, 57 (Prague, 1868).

In Sweden Linnarson has succeeded in giving a more complete classification than his predecessor, without being able to clear up certain obscure points of superposition and of succession.

Here is the *résumé* :—

TABULAR VIEW OF THE LOWER PALÆOZOIC ROCKS OF SWEDEN.

<table>
<tr><td>Silurian System.</td><td colspan="2">Klinte sandstone of Scania.
Upper Graptolites shales.
Brachiopod shales.</td><td>Silurian System.</td></tr>
<tr><td rowspan="2">Ordovician * System.</td><td>Trinucleus shales.
Chasmops limestone.
Middle Graptolites shales.
Orthoceras limestone.</td><td>Second fauna.</td><td>Cambrian System.</td></tr>
<tr><td>Lower Graptolites shales.
Ceratopyge limestone.</td><td rowspan="2">Supra-Primordial fauna.</td><td rowspan="4">Taconic System.</td></tr>
<tr><td rowspan="3">Cambrian System.</td><td>Dictyonema shales</td></tr>
<tr><td>Olenus shales.
Paradoxides beds.</td><td>Primordial fauna.</td></tr>
<tr><td>Fucoid sandstone.
Eophyton sandstone.</td><td>Infra-Primordial fauna.</td></tr>
</table>

Compared with the section of the Taconic System, the two lower divisions represent the two groups with *Eophyton* and *Arenicolites* of Newfoundland, or the lower part of the St. Albans Group, — the Infra-Primordial fauna.

The "*Paradoxides* beds," with the six subdivisions that Linnarson has found there, represent the zone with *Paradoxides* at Newfoundland, Braintree, and St. John, New Brunswick. The "*Olenus* shales" correspond to the Georgia slates with *Olenelli*, and these two zones together form the true Primordial fauna.

Then the "Dictyonema shales," added to the "Ceratopyge limestone" and the "Lower Graptolites shales," represent the Supra-Primordial, or the Groups of Phillipsburgh, Swanton, and Potsdam.

It must be remarked that Linnarson, in placing the "Ceratopyge limestone" and the "Lower *Graptolites* shales" in his "Ordovician System," had reached the conclusion that the fauna of Hof was not Primordial, contrary to the opinion of Barrande; and according to his memoir it ought to belong to the second fauna.

NORWAY. — The environs of Christiania in Norway present an uninterrupted series of the Taconic System, much more complete than that of Sweden.

* From *Ordovices*, a people inhabiting the northern part of Britannia Secunda, or Cambria, now Wales.

Here is the general theoretic section given by Messrs. Kjerulf and Brögger: —

TABULAR VIEW OF THE LOWER PALÆOZOIC ROCKS OF NORWAY.*

<table>
<tr><td rowspan="4">Etage 3.
142 feet.</td><td>3 c. 3 c γ. Der Orthocerenkalk.</td><td colspan="2">Second fauna.</td><td>Cambrian System.</td></tr>
<tr><td>3 c β. Der Expansusschiefer.
3 c α. Der Megalaspiskalk.</td><td rowspan="2">Swanton slates.</td><td rowspan="4">Supra-Primordial fauna.</td><td rowspan="6">Taconic System.</td></tr>
<tr><td>3 b. Der Phyllograptusschiefer.</td></tr>
<tr><td>3 a. 3 a γ. Der Ceratopygenkalk.
3 a β. Der Ceratopygenschiefer.
3 a α. Schiefer und Kalk mit Symphysurus incipiens.</td><td rowspan="2">Phillipsburgh or Point Lévis Group.</td></tr>
<tr><td rowspan="2">Etage 2.
150 feet.</td><td>2 e. Dyctyonemaschiefer.</td></tr>
<tr><td>2 d. Kalk mit Peltura.
2 c. Schichten mit Eurycare.
2 b. Schichten mit Parabolina.
2 a. Olenus-Niveau.</td><td>Georgia slates or Olenus Zone.</td><td rowspan="2">Primordial fauna.</td></tr>
<tr><td>Etage 1.
80 feet.</td><td>1 d. Paradoxides Forchhammeri, Ellipsocephalus, Obolella.
1 c. Paradoxides Tessini, Par. regulosus, Conocephalites.
1 b. Paradoxides Kjerulfi, Acrotreta, Hyolithes.</td><td>Acadian or St. John Group. Braintree and St. Mary's Bay (Newfoundland), or Paradoxides Zone.</td></tr>
<tr><td colspan="5">Gneiss, Granite, Syenite, Porphyry, Gabbro, Labradorite, Diabase, and Diorite.</td></tr>
</table>

The first division, or Etage 1, represents the zone of *Paradoxides*, and is equivalent to the zone of Paradoxides in Newfoundland, Massachusetts, and New Brunswick. It is called "*Paradoxides* slates of Krekling" near Vestfosen. After its deposit there was a dislocation strongly marked at Sandswær near Christiania, which seems to be contemporary with the dislocation at Newfoundland, St. Mary's, Trinity, and Conception Bays, and St. John, New Brunswick. For more than twenty years Prof. Kjerulf has recognized this resemblance, and has placed this first division in the Taconic System. The fossils are: *Paradoxides Kjerulfi, P. Tessini, P. rugulosus*, and *P. Forchhammeri; Arionellus primevus* and *A. difformis; Conocephalites ornatus*, and *C. Sulzesi; Ellipsocephalus circulus; Liostracus Linnarsoni* and *L. microphthalmus; Dolichometopus Suecicus;* twenty species at least

* See *Udsigt over det Sydlige Norges Geology*, by Theodor Kjerulf, 4to, with Atlas, folio (Christiania, 1879); and *Die Silurischen Etagen 2 und 3 im Kristianiagebirt und auf Eker*, by W. C. Brögger, 4to (Kristiania, 1882).

of *Agnostus; Hyolithes socialis, H. tenuistriatus,* and *H. plicatus; Lingula, Orthis, Obolella, Acrothele,* and *Acrotreta.*

This fauna indicates the lower part of the true Primordial. But the American Infra-Primordial has not yet been recognized in Norway.

The second division (Etage 2), or "Die *Olenus* schiefer," with an average thickness of 150 feet, is subdivided by Mr. W. C. Brögger into five parts, called 2 *a*, 2 *b*, 2 *c*, 2 *d*, 2 *e*. The first is especially the level of the *Olenus;* then come the beds with *Parabolina*, closely allied to the genus *Olenus*, with which it has often been confounded; then the *Eurycare*, the *Peltura*, and a schist with *Dyctyonema* (*Graptolites*), forming the base of the Supra-Primordial fauna. Beside the trilobites belonging to the genera already cited, and two or three others, forming a total of twenty-one species, only one *Orthis*, one *Lingula*, and one *Obolus* have been found.

It is clearly the same fauna as that of the Georgia slates, or zone of *Olenellus*, of America.

In the lithology the assimilation is the same; for in Norway the slates enclose small limestone lentils, in the middle of which the fossils are found by preference, just as in Vermont.

The third division (Etage 3), or "Die Asaphus Etage" of Brögger, follows that with *Olenus* in concordant stratification, as is shown in a fine section of the railroad to Vestfosen near Christiania.*

In this remarkable memoir, the first, or 3 *a* group, which is subdivided into *α*, *β*, and *γ*, has a mixture of primordial trilobites, with forms belonging to the second fauna, resembling the deposits at Hof, at Point Lévis, and at Phillipsburgh. The *Ceratopyge* are so near the *Olenus*, that Prof. Sars has put them in the same genus. The genus *Dikelocephalus*, so remarkable in America, is found in Norway in the subdivision *γ* of the group 3 *a*. Further, there are also *Agnostus*, *Cyclognathus*, a genus allied to the *Peltura* and the *Olenus*, and one *Parabolinella*. On the other hand, the following genera of trilobites make their first appearance: *Amphion, Cheirurus, Holometopus, Harpides, Triarthrus, Megalaspis, Niobe, Symphysurus,* and *Ampyx;* all belonging to genera that made their first apparition in America at the same epoch.

In this division 3, subdivision 3 *a*, mollusks are more rare than in America; there are only one *Orthoceras*, one *Bellerophon?* one *Orthis*, two *Lingula*, one *Lingulella*, two *Obolus*, one *Obolella*, one *Discina*,

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* Die Silurischen Etage 2 und 3 in Kristianiagebirt und auf Eker, by W. C. Brögger, p. 29 (Kristiania, 1882).

and two *Acrotreta;* all having a decidedly primordial aspect. *Graptolites* are also found.

On the whole, the parallelism of the lower part of division 3 (Etage 3), and of the "Dyctonemaschiefer," with the Phillipsburgh and Point Lévis Group, can hardly admit of doubt.

Above come the schists with compound Graptolites, called "Phyllograptus schiefer," or 3 *b*, in which are found the *Graptolites* of Point Lévis. Then comes group 3 *c*, the two first subdivisions of which, 3 *c α* and 3 *c β*, form, with the 3 *b*, a mass of sixty feet average thickness of schists with *Graptolites* at the base, and then with limestone lentils filled with fossils, four fifths of which belong to the second fauna, the primordial fauna only being represented by one *Agnostus*, and some Brachiopods (*Orthis, Lingula, Lingulella, Discina?*), and one *Acrotreta.*

The schist with *Graptolites*, or 3 *b*, may be considered as equivalent to those of Point Lévis, Quebec, and Swanton, of the "Swanton Group." But farther up there is an important hiatus in the series of Norwegian fossils; those of the subdivisions 3 *c α* and 3 *c β* appearing to belong to the fauna of the subdivision 3 *c γ*, or "Orthocerenkalk," which in Norway certainly represents the Chazy and Black River of the second fauna in America.

A slight tie, however, unites the Norwegian fauna of 3 *c α* and 3 *c β* to the Supra-Primordial fauna; and considering the great distance of Norway from the typical Taconic region of America, it seems probable that the two faunæ were contemporary, and we have there the last term of the Taconic System.

It is certain that the conditions in America for the development of organic life in the Taconic seas were far more favorable than those of Scandinavia, and it is not strange if we find important differences in the evolution of life in two regions so far distant from each other.

The small division of the "Potsdam sandstone" has no representative in Scandinavia, nor in Bohemia; not that the sediments were arrested in this part of Europe during the time that this formation was deposited, but because we have not yet the means of finding the parallelism. It is possible that the "*Porambonites* schicht" (schists with *Spirifer porambonites*), of only three feet thickness, which form the base of the "Orthocerenkalk" at the section of Vestfosen near Lunde, Norway, may be the representative of the Potsdam; and in Dalecarlia (Sweden) the "Oboluskalk," containing *Obolella*, only six to ten feet thick, which has been found between the "Ceratopyge lime-

stone" and the "Phyllograptus schiefer" at the base of the "Orthoceras limestone" by S. L. Tornquist, and referred by him to the "Tremadoc Group" of England. The section of Vikarbyn, in which the "*Obolus*-Konglomerat" and "*Obolus*-Gruskalk" lie on the granite, may offer the equivalent of the Potsdam. (See "In Ofversigt ofver Bergbyggnaden in om Siljäusomr Œdet," Dalarne, 4to, Stockholm, 1883.)

If the Potsdam really exists in Europe, it is in the Iberian peninsula and in Brittany, where the sandstone of Cabo-Busto with *Scolithus* in the Asturias (Spain), the quartzites with *Bilobites* of Bussaco (Portugal), and the sandstones with *Scolithes* of Brittany (France) are in the same stratigraphic position, especially in the province of Caceres in Spain, and in Portugal, where the sandstones with *Scolithes* are deposited on the Taconic schists, denuded and eroded, exactly like the "Red Sandrock" of Vermont resting on the denuded and eroded Taconic schists of America.

The great dislocation of the Green Mountains drove from the American regions all the types of the second fauna that had made their appearance in the upper parts of the Taconic schists. Then during the special deposit, limited in time and space, of conglomerates, sands, and limestones that have been called "Potsdam sandstone," certain characteristic primordial forms shed a last light before disappearing forever.

I speak especially of the trilobites, the evolution of which is easier to follow than that of organisms placed lower in the scale of the animal kingdom.

The dislocation that ended the Potsdam deposits ended also the existence of the primordial fauna in America; and we pass suddenly into the second fauna with the "Calciferous and Chazy divisions." The sediments were changed, and all was prepared in the American sea in which the deposit was made of the series of the "Champlain System," or "Cambrian" proper, for the exclusive development of the second fauna.

Nevertheless, it is well to notice that as yet several animal forms of the second fauna which made their first appearance in the "Phillipsburgh and Swanton Groups" have never reappeared in America, while they have had their complete evolution in Europe. For instance, I will cite the genus *Amphyx*.

And further, according to the careful palæontological researches of Prof. A. Hyatt, no true *Endoceras* with cone in cone structure has yet been found below the true "Chazy limestone" and "Calciferous sand-

rock." All *Orthoceratites* found in the Taconic belong to the genera *Saunionites*, *Piloceras*, and true *Orthoceras*. Finally, the *Lituites* of Phillipsburgh are very rare in America, and disappear almost totally with the "Taconic System."

VI. Taconic *versus* Cambrian and Silurian.

The time has now come to make clear the prior right and the real advantage to be found in the use of the term "Taconic System," instead of the so generally employed expressions "Cambrian" and "Silurian," to designate the strata enclosing the primordial fauna. First, it is a question of justice; and it is hardly possible that the third International Geologic Congress, which is to meet at Berlin, should fail to consider the names to be chosen for the great divisions of formations on the geological map of Europe.

Facts and dates will prove that America has the right to name one of the great systems, or series of strata, and that the observations made and work done on this side of the Atlantic have first made known the true base of the stratigraphic scale.

Murchison, not wishing to use the German name of "Grauwacke," nor the French term "Terrain de transition," explains as follows the origin of the terms Silurian and Cambrian.*

"At this time [1835] I proposed the term *Silurian*, and it came about in this way. My friend, the eminent French geologist, Élie de Beaumont, seeing what a clear classification I had made out by order of superposition and characteristic fossils in each descending formation, earnestly urged me to adopt a name for the whole of the natural groups. Seeing that the region in which the best types of it occurred was really the country of the Silures of the old British king Caractacus, I adopted that name [Silurian]. I had seen that all geological names founded on mineral or fossiliferous characters had failed to satisfy, and that fanciful Greek names were still worse. Hence it seemed to me that a well-sounding geographical term, taken from the very

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* *Cambria*, from the Latin *Cimbri* (robbers), and from the Celtic *Cymry*, the *Britannia secunda* of the Romans, comprehended the whole of Wales from the river Severn to the river Dee. Three tribes inhabited it: on the south, the Silures (*Siluria*); on the west, the Dimetes (*Dimetia*); and on the north, the Ordovices (*Ordovicia*). All these names have been used by English geologists, who have also proposed other Welsh names, such as Menevian, Pebidian, Arvonian, Longmynd, Llamberris, Harleck, Festiniog, Tremadoc, Arenig, Caradoc, etc. The little principality of Wales has furnished more geographical names to geology than any other country.

region wherein the classification had been elaborated, and where every one might go and see the truthfulness of it, was the best." *

"The word *Cambrian* was first used in print in the year 1836. . . . . It originated in the following manner. . . . . On sending a copy of my new classification to M. Élie de Beaumont, that eminent geologist, wishing to mark strata separated by lines of dislocation by separate names, suggested the propriety of further distinguishing those last-mentioned unconformable and inferior rocks by the term *Hercynian*, as taken from the Hartz mountain in Germany, where, as he then believed, the oldest slaty group would prove to be of higher antiquity than the strata to which I had applied the word *Silurian*. Unwilling that the name for these infra-Silurian rocks should be taken from a foreign country, in which no precise palæozoic horizon had then been fixed, I at once urged Professor Sedgwick to apply to his slaty rocks, which were confidently believed to be inferior to my own, some term on the same geographical principle by which I had been governed in proposing *Silurian*.

"I even ventured to suggest the word *Snowdonian*, because I knew that my friend then considered the northwestern portion of the Welsh chain to be made up of the oldest fossiliferous masses; but preferring a more comprehensive geographical name, he took that of *Cambrian*. With this arrangement we both felt certain that no anomaly could be introduced into the lower palæozoic classification, as the relations and fossil contents of mineral masses, which were contiguous, must be eventually cleared up without fear of error or the introduction of theoretical views." †

According to these quotations, Élie de Beaumont was the inspirer of the geographic names in *ian* to designate stratigraphic groups. This is only a partial truth. De Beaumont only proposed two geographic names, the *Grès Vosgien* in 1841, and the *Cumbrien* (from Cumberland) in 1847. The last was an endeavor to make Murchison and Sedgwick harmonize, and to designate the strata containing the second fauna. Neither of the adversaries accepted this transaction. But de Beaumont had been struck with the success of the names *Portlandien*, *Kimmeridien*, *Corallien*, and *Oxfordien*, proposed and

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* Life of Sir Roderick I. Murchison, vol. i. p. 227 (London, 1875).

† "On the Meaning originally attached to the term 'Cambrian System,' and on the Evidence since obtained of its being geologically synonymous with the previously established term 'Lower Silurian.'" By Sir Roderick I. Murchison. In the Quarterly Journal of the Geological Society of London, vol. iii. pp. 166, 167 (1847).

employed since 1832 by Jules Thurmann, in his "Essai sur les Soulèvements jurassiques du Porrentruy." Thurmann, a geologist of new and original ideas, was the first to recognize the utility of geographic terms uniformly ending in *ien*, and who first used them in 1832 for his very remarkable orographic classification of the Jura Mountains. In 1834, pursuing the same idea, he found and employed the name *Néocomien*, to designate the lower part of the cretaceous formation, called at that time the *Crétacé du Jura*, or *Jura-Crétacé*. This name was proposed and employed in a reunion of the Geological Society of the Monts-Jura, at Besançon, on the 1st and 2d of October, 1835, according to a letter that Thurmann wrote to Élie de Beaumont, which the latter published in the seventh volume of the Bulletin de la Société Géologique de France, 1er Série, page 209, where we read, "Je (Thurmann) propose de donner le nom de terrain Néocomien (*Neocomensis*), c'est à dire de Neuchâtel comme on dit Portlandien, Oxfordien, etc."

The coincidence of Élie de Beaumont's suggestion, in 1835, of the use of the word *Hercynian*, with the creation of the term *Neocomian*, which Thurmann had communicated to him, shows that the initiative of these terms ending in *ien* or *ian* comes truly from Thurmann, as the dates of the published documents prove.

Sedgwick and Murchison had made a friendly association with each other to study the ancient stratified rocks of England; Murchison exploring the grauwackes of Hereford, Radnor, and Pembroke counties, while Sedgwick studied especially the slaty or schistose region of the North of Wales. The latter quickly recognized the succession of the principal groups of schist, as well as the dislocations that have affected them. He saw very well that his "Group of Bala" rested in discordance of stratification on the schists of Festiniog and of Longmynd; and as no fossils had been found in the strata below the Group of Bala, their thickness and their structure were not at first studied. It sufficed to know that their thickness must be very great and their structure very complicated, especially in the counties of Pembroke, Cardigan, and Caernarvon. The attention of Sedgwick was concentrated on the Group of Bala. He recognized there a series of strata, which he subdivided into two portions, containing an entire special fauna. Sedgwick did not occupy himself with the study of it in Shropshire and Montgomeryshire, where Murchison found it, and took it to form his "Lower Silurian." Murchison gave as his excuse, that he thought the fossils collected by Sedgwick were different from those he had placed in his "Lower Silurian," and that he was much sur-

prised to learn that Sedgwick had only found Silurian fossils in his Cambrian. Consequently, he says, "the Cambrian is not inferior in its position than the lowest stratified rocks of my Silurian of the region of Shropshire and the adjacent part of Montgomeryshire, as we had supposed, but is merely extension of the same strata." *

In order to fix the date, Murchison hastened to publish his "Silurian System," in 1839, taking great care to have all the fossils he had procured described by such specialists as Agassiz, Sowerby, and especially Lonsdale. He had also the skill to submit some portions of his manuscript, principally the Introduction, to his friend Sedgwick, to whom he dedicated it, and he included in his volume, as his own, a quantity of observations of very great value by other geologists, who had with great liberality communicated them to him. We will mention the Rev. T. T. Lewis, vicar of Aymestry, who had cleared up and classed all the strata of his neighborhood before Murchison went there, and whose talents as an observer, according to Prof. Phillips, a good judge, were at least equal to those of Murchison.†

Sedgwick, with his integrity and fairness of character, and simplicity of manners, thinking only of the progress of stratigraphy and geology, of which he was certainly the most learned representative and the most capable since the death of "Strata Smith," failed to see at first the great benefit of this publication, which in some sort cut the grass from under his feet, and stole a march upon him. He continued his studies, collecting his materials patiently, with the greatest care, above all observing with great knowledge and ability all the superpositions, dislocations, and associations of strata, and slowly made ready the publication of his fossils in 1855, under the title, "A Synopsis of the Classification of the British Palæozoic Rocks, by Adam Sedgwick, with a Systematic Description of the British Palæozoic Fossils in the Geological Museum of the University of Cambridge, by Frederick McCoy" (Royal 4to, Cambridge.)

It is true, that meanwhile a very active controversy, especially on the part of Murchison, arose between the associates. They became irreconcilable enemies; and a complete rupture, much to be regretted in the interests of science, took place between them.

It is now admitted that Sedgwick was right to insist upon the independence of the second fauna, and its separation from the third fauna, which alone has the right to be called "Silurian." That from the

* Siluria, 1st ed., 8vo, p. 8 (London, 1854).

† Life of Murchison, vol. i. p 242.

first observations he recognized a different system from that of the groups of Wenlock and Ludlow, and that in calling it "Cambrian" he followed the rules recognized in stratigraphy for establishing the great formations or systems.

But we must go back, to show the progress accomplished, first outside of England, and then in England itself.

The publication of "The Silurian System," in 1839, was truly an event, and marks an important point in the progress of geology. Nevertheless, it is well to say that this book had at first hardly any influence in America, and only after the visit of de Verneuil, in 1846, did it attain a certain limited influence.

Since 1836, Vanuxem, Emmons, and Conrad had studied with the greatest success the "Transition formations" of the State of New York. The beds being in part horizontal, or nearly so, and succeeding each other in a receding series, the American geologists easily established a good classification without having to make the difficult connection and joining which arrested Murchison and Sedgwick in England.

In Europe the publication of the "Silurian System" had at once a very great influence, owing to very different causes. In the first place, the author went over Europe in all directions, trying everywhere to recognize and establish his Silurian classification.

There was a sufficient resistance by the German, Scandinavian, and Russian geologists; but he succeeded in surmounting it, thanks to the French geologists, always much disposed to Anglomania. Barrande it was, above all others, who made the fortune of the "Silurian System." Exiled at Prague with the royal family of France, Barrande had already for some years been studying the basin of Bohemia, systematically collecting both fossils and geological sections. The want of points of comparison, and the resistance of the Bohemian geologists and palæontologists, who declared that the geology of that country was unique, and unconnected with anything similar in the earth's history, caused Barrande to receive the first copy of the "Silurian System," at Vienna, in 1840, with the same joy that a sailor by night in a fog perceives a lighthouse. And in gratitude for the great service this book rendered him, he not only employed the term "Silurian," but extended it to strata far below the level of those described by Murchison, adding at once an average of ten thousand two hundred feet of beds containing the primordial fauna, his division C, — entirely unknown to Murchison and Sedgwick, — and also his azoic beds A and B.

Barrande, although having heard of the different views of Sedgwick and Murchison, and the controversy which broke out in 1846 and 1847 between them, could only form an opinion of the worth of Sedgwick's claims by studying the question in Wales and Shropshire, which was materially impossible for him at that time in his life, — the little time at his disposal being given to his studies on the geology of Bohemia.

Sedgwick published his "Synopsis," with fossils by McCoy, in 1855, so that Barrande was without it in his classification of 1850, and he makes no mention in his publications in the Bulletin de la Société géologique de France, 1851, nor in his first volume of the "Système Silurien du Centre de la Bohême," 1852, of the "Cambrian system," of which he had no cognizance, palæontologically at least. Otherwise, with his great loyalty and love of justice, Barrande would doubtless have recognized the real rights of Sedgwick and his "Cambrian System," as he did later those of the "Taconic System," of which he was equally ignorant, though published in 1846. His classification once published and his great work begun, Barrande could not vary from the term adopted, or change his title.

These are Barrande's divisions of the "Silurian System" in Bohemia.

TABULAR VIEW OF THE "SYSTÈME SILURIEN DU CENTRE DE LA BOHÊME."

<table>
<tr><td>Upper Silurian.
900 feet.</td><td colspan="2">H. Hluboceper group.
G. Braniker group.
F. Koniepruser group.
E. Kuchelbader group.</td><td>Third fauna.</td><td>Silurian System.</td></tr>
<tr><td rowspan="2">Lower Silurian.
16,200 feet.</td><td colspan="2">6,000 feet. D. { d5. Kœnigshofer group. d4. Zahorzaner group. } Colonies of the third fauna exist in both groups.
d3. Vinicer group.
d2. Mont Drabow group.
d1. Voseker group.</td><td>Second fauna.</td><td>Cambrian System.</td></tr>
<tr><td colspan="2">Porphyry.

1,200 feet. C. Ginecer schists, or Protozoic slates of Ginetz and Skrey.

9,000 feet. { B. Przibramer grauwacke.
A. Przibramer schiefer.</td><td>Supra-Primordial fauna wanting.
—
Primordial fauna, only the Paradoxides Zone.
—
Infra-Primordial fauna wanting, except a few Arenicolites.</td><td>Taconic System.</td></tr>
<tr><td colspan="5">Granite and Gneiss.</td></tr>
</table>

Barrande insists on the great difference between the primordial fauna of Bohemia and the second fauna. He says, "Nos étages C et D peuvent être cités, comme présentant la difference la plus absolue que l'on connaisse entre les faunes de deux étages consécutifs." The cause of this is the total absence of the Supra-Primordial fauna in Bohemia.

Murchison hastened to profit by the excellent work of Barrande. and, before Sedgwick had finally decided to publish his "Synopsis," — long since announced and only appearing in 1855, although dated 1851 and 1852 in the Introduction, — Murchison, always on the *qui vive*, brought out a new and more popular edition, in octavo form, of his "Silurian System." Without consideration, he not only boldly placed in his "Lower Silurian" the formations of Caradoc and Llandeilo, or Bala Group of Sedgwick, but he went further, and placed there also the "Lingula flags" and the "Longmynd or Bottom rocks," and entirely suppressed the "Cambrian."

He did even more; the success of the term "Silurian" caused him to forget all prudence, and he included in his new edition of the "Silurian System" all the palæozoic series under the unique title of "Siluria"; placing under this rubric of "Siluria" the primordial, second, and third faunæ, the Devonian, Carboniferous, and even all the New Red Sandstone of Russia (*Dyas* and *Trias*), which he called by the Russian name "Permian." In the second and third editions of "Siluria," in 1859 and 1867, the description of strata given always increased in number, citing already the Jurassic and Cretaceous, and if another edition had appeared, the whole stratigraphic series would have passed under the title "Siluria," stopping only at the glacial Quaternary.

This excess of Siluria and Silurian brought on a reaction, and Barrande himself gave the signal for it.

Let us remember that forty years ago, or even thirty, communication was not so easy as it is now, and that publications in one country and in one hemisphere reached their destination in another with much difficulty, or not at all.

So we must not be astonished if, notwithstanding the active and persistent researches of Barrande to find all that had appeared upon the primordial fauna and the rocks that enclose it, all the memoirs and reports of Emmons had entirely escaped him. With a truly prophetic intuition Barrande had successively announced the extension of the primordial fauna he had established in Bohemia in 1846 to Sweden, Norway, England, Spain, the Upper Mississippi, Braintree near Boston, Georgia, Texas, and Missouri.

This was not done without opposition, the centre of which was in England, where no one accepted it, — Sedgwick no more than Murchison and the Geological Survey. Barrande, in his fine and courteous way, called the "Primordial fauna" *Mademoiselle de Trop* (Miss of Too-much). In truth, it was too much for Murchison, who thought he had included the whole in his "Silurian System," and it was also very *mal à propos* for Sedgwick, who had caused McCoy to describe all the fossils found in his "Cambrian," and who was right in regarding them as the most ancient forms, the base of organic types.

Lastly, the Geological Survey, with its numerous staff of assistants and collectors of fossils, and the extreme care with which it studied Wales and the Malvern Hills, did not like to admit that a stranger, in a short stay in London, and during a rapid visit to other points of the country in the winter of 1850–51, had been able to find an entirely new fauna which had completely escaped them.

No one has shown greater elevation of mind, or carried to a higher point the moral distinctions in his geological and palæontological discoveries and researches, than Barrande. He had consecrated the greater part of his time and resources for fifteen years to "the *creation* of the primordial fauna," to follow the expression of D'Omalius d'Halloy, and when in 1860 he received from Dr. Emmons and Billings the documents published on the "Taconic System," he did not hesitate a moment in recognizing and proclaiming the right of priority for Emmons and the "Taconic System." He says: —

"At its origin, that is to say from 1838 to 1844, this Taconic System was presented as founded on petrographic and stratigraphic observations, and constituted simply the *sedimentary base*, according to the American expression. It was still without any characteristic fauna. But in 1844, Dr. Emmons having discovered in this formation fossils before unknown, his Taconic System for him represented the *palæozoic base*.

"This expression, used on the other side of the Atlantic, is evidently equivalent to that of 'Primordial fauna,' which I have applied to the trilobitic group, the oldest of Bohemia, defined for the first time in my *Notice préliminaire*, in 1846. It is known that the *Lingulæ* which characterize the corresponding horizon of Lingula flags in Wales, that is, in the Cambrian region of England, were only discovered by Mr. Davis in 1845. (*Siluria*, 2d ed., p. 43, 1859.)

"In comparing these dates it is clear that Dr. Emmons had first announced the existence of a fauna anterior to that which had been established in the 'Silurian system' as characterizing the 'Lower

Silurian' division, and which I have named *Second fauna*. It is then just to recognize this priority, and I think it all the more fitting to state it at this time, that it has not been claimed to this day." *

A more complete demonstration and justification of the priority of the "Taconic System," of its position at the base of all the systems of strata, and of the large place it holds in the stratigraphic scale, could not be desired.

It is evident that, if Barrande had seen the memoirs of Emmons when they appeared, he would have used the name "Taconic" to designate all that lower part of the most ancient strata of Bohemia which, having nothing better, he called divisions A, B, and C of the "Lower Silurian."

There is no doubt, also, that if Sedgwick and McCoy had published fifteen years sooner the "Synopsis of the British Palæozoic Rocks and Fossils," Barrande would have recognized the "Cambrian" in his division D of the quartzites with the second fauna. But Barrande published his "Système Silurien de la Bohême" in 1852, while Sedgwick first published his great work in 1855, and the Taconic documents of Emmons did not reach Barrande until 1860.

These dates explain and answer all objections. There can no longer be any question as to including in one system the primordial, second, and third faunæ; to do this would be in the actual state of our knowledge as great an anachronism as to make one system of the strata containing the triassic, jurassic, and cretaceous faunæ. Thus, Linnarson, notwithstanding the slight thickness of the strata of the lower Palæozoic in Sweden, has not hesitated to recognize three great formations, which he calls *Cambrian*, *Ordovician*, and *Silurian*. This *savant* was not concerned with the question of priority, nor to know precisely the signification of the term "Cambrian." As to the term "Ordovician," † put forward lately by some English geologists (Prof. Charles Lapworth and others) to designate the rocks containing the second fauna, there is no more reason to accept it than the name "Cambro-Silurian" proposed formerly by Sir Charles Lyell. The term "Taconic," brought forward so strikingly by Barrande, is well known to-day; it has been used in Germany, Norway, Spain, Italy, and France. I have used it in the two editions of my essay of a "Geological Map of the World."

* "Documents anciens et nouveaux sur la Faune Primordiale et le Système Taconique en Amérique," in Bull. Soc. géol. de France, 2 sér., tom. xviii. p. 225, 1861.

† Dr. Emmons gave the name "Champlain," in 1842, to the same group of rocks containing the second fauna.

The name "Cambrian" can be justly applied only to th series of rocks enclosing the second fauna. To wish to extend it to the strata of the primordial and second fauna, as the school of Cambridge in England has tried to do for several years, is to fall into the same fault that Murchison is reproached with, who, in his "Silurian System," extended the name "Silurian" to the second and third faunæ. Sedgwick and McCoy were completely ignorant of the existence of the primordial fauna, and in their "Synopsis," etc., of 1855, there is not a single primordial fossil. With such a hiatus and an absolute ignorance of the order of appearance of the organic types, and of the first term of the palæontologic evolution, how can one try to apply the name "Cambrian" to the base of the stratigraphic scale? It would be contrary to all the rules that have hitherto directed the classification and denomination of the great formations.

As Barrande has said, — for we must always return to him and quote him when we touch anything relating to the first three great faunæ preserved in the strata of the earth, — the "moral aspect which accelerates or delays the solution of scientific questions should be considered in a spirit of equity and justice." The time for controversy and animosity has passed away. There are very few survivors; and by the close of the century, not one will remain of all those who have taken part in the discussion.

It is for the young generation of geologists now to render to each of the masters who created the classifications, and who were the first in the difficult work of deciphering and explaining the manuscript of the earth, that which is their due; taking into consideration the equilibrium of the general classification, the logic of registered facts, and, above all, the *priority!* On all these accounts I do not hesitate to propose to them, as a solution, the three groups or systems which follow: —

III. Silurian System, containing the third fauna.
II. Cambrian System, containing the second fauna.
I. Taconic System, containing the primordial faunæ.

Systems corresponding in time and space, and in the evolution of life, to three other great consecutive systems, such as, for example, the triassic, jurassic, and cretaceous formations.

The question of the relations and passage of one great fauna to another is a fact admitted to-day as incontestable, and which all the explanations by means of invisible faults and foldings of the uniformist school of absolute and mathematical rules can neither arrest nor suppress.

Barrande first discovered and showed in Bohemia the "Colonies" of the third fauna in the second fauna. Then I called attention to the "Colonies" of the second fauna in the primordial fauna of the borders of Lake Champlain. Dr. E. Kayser has recognized, in the Hartz and in Nassau, "Colonies" placed also in limestone lentils of the third or Silurian fauna, in the fourth or Devonian fauna. Prof. H. S. Williams has lately found in the State of New York, at Ithaca and Lake Canandaigua, a "Colony" of the fifth or Carboniferous fauna in the fourth or Devonian fauna.

Lastly, in India, New Zealand, California, in the Tithonic, the Rhetic, the Lower Dyas, the Laramie Group, etc., everywhere, at all degrees of the stratigraphic scale and in all latitudes, these passages exist; organic beings are mixed in sufficient proportions to connect all the links of the chain, and form a continual series of general evolution.

The great lines of the stratigraphic series are now distinctly drawn, at least for the northern hemisphere.

The European geologists have had the honor to recognize and create this magnificent classification in the chronological order of time which has passed since the earth has been inhabited. Upon one point they have been anticipated by their colleagues of America. The first degree of the scale, the most ancient of all the systems, was first recognized in the New World. It is only just that this discovery should be registered in the general classification.

To the European geologists I would say, America occupies a place in the history of geology which is but little below that occupied by Europe. Every day discoveries of great importance are made in America; and, as Prof. K. A. Zittel of Munich has lately said, after a rapid excursion across North America, "The time of great discoveries has begun in America; it is over in Europe. . . . . It is beyond question that the future development of geology and palæontology will be essentially influenced by America." By accepting the "Taconic System" and placing it in the scale of the formations, you will act with graceful courtesy.

To the American geologists I would say, you have a patriotic duty to fulfil. On your own soil, and by one of you, — an American in the full sense of the term, for Dr. Ebenezer Emmons never even went to Europe, — was found, and described and named for the first time, the primordial fauna and the beds that contain it. By employing the term "Taconic," you defend a right that since Barrande no geologist has disputed.

Finally, to all my geological fellow-workers, as well American

as European, to those of India, Australia, New Zealand, Java, and Africa, I ask you, in the name of justice, right of priority, and of equity, to make use of the "Taconic System."

VII. Conclusion.

The "Taconic System" comprehends all the strata in which the primordial faunæ are found. These faunæ are three in number.

The *Infra-Primordial*, which has as yet furnished only about ten fossils well characterized, all belonging to the inferior order of beings, and of a very simple organization. No trilobite has yet been found there with certainty. This number of from ten to twelve species will be doubled, and even quadrupled; but it is doubtful if it ever reaches fifty species.

The *Primordial* fauna properly so called — that of Bohemia and Scandinavia, including the great zones with *Paradoxides* and *Olenus* — is especially remarkable for the large trilobites, which hitherto have made their appearance suddenly, without prophetic prototypes to announce them. The species belong to the *Crustacea* (trilobites), *Pteropoda*, and *Brachiopoda*, with one or perhaps two *Cephalopoda*. The number of the different species is very limited, although there are from ten to thirty and forty to be counted together; and one can hardly number for the whole earth two hundred and fifty species. In future discoveries and researches we may reach twice and three times that number, but it is unlikely ever to reach one thousand.

The *Supra-Primordial* fauna, containing colonies of the second fauna in America and Scandinavia, is much richer in fossils. Hundreds of species are met with at once; all of the orders of Crustacea, Mollusca, Radiata, and Bryozoa. Many new and previously unknown forms make their appearance here. Already the number of fossils of this fauna of the upper part of the "Taconic System" reaches more than fifteen hundred species, and we may confidently look forward to great discoveries that will carry this number to three or even four thousand.

A peculiarity common to all the primordial faunæ, which was pointed out by Dr. Emmons when he made his discovery, is that the fossils are found in a sporadic way, — here and there, or entirely isolated, — contrary to the geographic distribution of the other faunæ, which are spread over and sometimes fill up the strata without interruption for hundreds of miles. We have here true centres of the appearance of species, or "centres of creation," as Prof. Edward Forbes has well expressed it. In consequence of their sporadic arrangement and tendency,

the Primordial faunæ are composed of species having a very limited geographic distribution; and it is very rare — although the forms are similar — that one species extends from one country to another, being common to two Taconic deposits, even when they are very near each other. This fact is worthy of notice by all who study the evolution of living beings, that at the Taconic epoch the marine zoöiogical provinces were more numerous, and much more limited in their geographical extension, and in the number of species and individuals, than in any other geologic epoch, including even that of the present day.

Lithologically, the greater part of the "Taconic System" is formed of slates, with quartzites here and there. and especially limestone lentils enclosed in the schists. The size of these lentils varies from that of a kidney or a man's head to dimensions of twenty, fifty, one hundred, and one thousand feet, and even more; they are scattered throughout the system, though more persistent and of larger size in the upper part.

With very few exceptions, nearly all the Taconic limestones are magnesian. Sometimes they are true dolomites, and contain no fossils. But if a very little magnesia is present, fossils are found; and they are more abundant when the magnesia is in very small quantity. Lastly, if the limestones do not contain any magnesia, and are clayey, then the fossils become directly more numerous, and it is in these lentils of pure lime that the Colonies of the second fauna are found.

Almost all observers who have studied and sought out the primordial fossils *in situ* have been struck by the total absence, or at least the very great rarity, of fossils in the slates enclosing the limestone fossiliferous lentils. We have the right to conclude that lime was a most important element in the existence of these marine creatures of the first period of life on the earth.

The "Taconic System" is of great thickness, with the exception of Scandinavia, where all the palæozoic strata are also of slight depth. In America it may be estimated at an average of ten thousand feet.

XII.

CONTRIBUTIONS TO THE BOTANY OF NORTH AMERICA.

By Asa Gray.

Communicated October 8th and December 10th, 1884.

1. *A Revision of some Borragineous Genera.*

This revision has become necessary by some recent discoveries. and by a more thorough study and appreciation of the characters of the various plants which have been referred, first by the De Candolles and afterward by Dr. Torrey and myself, to the genus *Eritrichium.* It is not pleasant to find that the conclusions now reached require considerable changes of accepted names which have received the sanction of the late Mr. Bentham in the recent Genera Plantarum, and that these changes might have been made or anticipated several years ago. But if it needs be so, the sooner they are made the better.

It plainly appears that too much has been made of the degree of obliquity of the nutlets, of their extension above the gynobase, and of the extent of their attachment to it, or, which is nearly the same thing, of the amount of growth, if any, of the developing nutlets above or below their insertion upon the more or less elevated axis (*gynobase*) which intervenes between the common torus and the style.* It seems to me equally clear that there are too great differences from species to species in *Echinospermum*, *Cynoglossum*, *Omphalodes*, *Eritrichium*, and the various plants which have been referred to these genera, to justify the two tribes *Cynoglosseæ* and *Eritrichieæ.* So that, indeed, it seems necessary to follow De Candolle in this respect, by referring all the quadrinuculate genera with lateral or introrse-basal insertion of the nutlets to the *Cynoglosseæ*, to be divided into sections as well as may be practicable. This tribe should even include *Moltkia* (*cœrulea*),

* As Turczaninow long ago rightly expressed it, all the part to which the nutlets are attached is gynobase, whether it be depressed, pyramidal, conical, or subulate, or even filiform. Only the free portion above is the style.

Lehm., the nutlets of which separate from the very low-pyramidal gynobase by a manifestly lateral scar.

A few notes upon the principal genera concerned may serve as an introduction to the following systematic exposition of certain mainly North American *Borraginaceæ*.

Cynoglossum, Tourn. Some recent authors have ignored a character (peculiar to this genus and to a part of *Omphalodes*) which was well delineated by Schkuhr almost a hundred years ago, and noted by Alphonse De Candolle in the Prodromus, namely, the carrying away by the apex of each nutlet of an exterior portion or "lacinula" of the indurated and persistent style, by which the four nutlets, after splitting off from the gynobase from below upward, are for a while suspended. Although in some species the nutlets are nearly horizontal on a depressed gynobase, in others they form a low or even a considerably elevated pyramid, with corresponding elevation of the gynobase; and the areola of attachment, or scar, varies from "*supra medium*" to very manifestly *infra medium* of the ventral face. The fruit of *C. cœlestinum*, Lindl., would refer this species rather to *Omphalodes*.

Paracaryum of Boissier does seem to be a too heterogeneous and ill-limited an assemblage. As founded in 1849, and as maintained in the Flora Orientalis (1879), it includes *Lindelofia* of Lehm., 1850, although the character calls for included stamens, which is not quite true of the latter. It also calls for a funnelform corolla, with tube more or less elongated; and upon this character the genus apparently may stand, whether including or excluding *Lindelofia*, Lehm. Apparently this should be included; for the anthers emerge more or less from the throat of the corolla in *P. heliocarpum*, *P. angustifolium* or *azureum*, &c. But whether Boissier's name, given to a wider group, or Lehmann's stricter but rather later name, should be adopted, is a nice question, which I am not called upon to determine. The species with short corolla will, upon this view, fall back into *Omphalodes*, *Rindera*, and *Echinospermum*.

Echinospermum, Lehm. It seems hardly correct to attribute this genus to Swartz, simply because (as Lehmann states) he suggested the name, while the published species with which his name is indirectly connected belong to *Cynoglossum*. It would appear that a better view is taken of this genus by Bentham in the Genera Plantarum than by C. B. Clarke in the Flora of British India. The latter would in effect restrict the genus to the *Lappula* group, in which alone, or mainly, are the nutlets attached up to their apex. In some of these (as *E. Redowskii*) the nutlets are "attached above their base"; but

in most, from very base to apex. In the group of which *E. deflexum* is the type, the scar is more or less supra-basal (in *E. hispidum* almost central and oval), and the apex of the nutlet is more or less free beyond it. *E. glochidiatum*, A. DC., which Bentham refers to *Paracaryum*, is surely a true *Echinospermum*, allied to *E. Virginicum*. *E. canum*, Benth. in Royle, Ill., which C. B. Clarke takes to be "the type of the genus *Echinospermum* as described in the Genera Plantarum," but which he refers to a glochidiate section of *Eritrichium*, is surely of the former genus. As to the exact position and length of the scar, Bentham's character of his *Eritrichieæ*, "nuculis . . . apicibus circa stylum plus minus prominentibus erectis *liberis*," applies to some, but not to all, of the plants he referred to *Echinospermum* and to *Eritrichium*. The importance given to this character and to the corresponding height of the gynobase in the Cynoglossoid genera has not led to good practical results. The glochidiate armature of *Echinospermum* and *Cynoglossum* may still be regarded as essential to the character.

Sclerocaryum is with good reason referred back to *Echinospermum* by Boissier. Its stout spines are not indistinctly glochidiate at the blunt apex. *E. Sinaicum* (*Eritrichium Sinaicum*, DC.) is apparently a congener.

Echinoglochin, Gray, Proc. Am. Acad. xii. 163, and Syn. Fl. ii. 190, I would still retain as a section of *Echinospermum*, coming nearest to *Krynitzkia*. Also the section *Homalocaryum*, A. DC., now containing a good number of species, should be kept distinct from the section *Lappula*. In the supra-basal insertion of the nutlets of some (but not all) of the species, as well as in habit, this group comes nearest to *Cynoglossum* and to *Omphalodes*. In the *Lappula* section the published name *E. Fremonti*, Torr. in Pacif. R. Rep. xii.² 46, has been accidentally omitted from Syn. Fl. ii. 190. It is a synonym of *E. Redowskii*, var. *occidentale*.

Omphalodes, Tourn. By leaving *O. linifolia*, *O. littoralis*, and *O. amplexicaulis* in this genus, Boissier and Bentham seem to abandon most of the ground on which the former's genus *Paracaryum* rests, except as to the longer-flowered species. For the species of *Omphalodes* above mentioned have a high-pyramidal gynobase, on which the nutlets are borne, for the most part in an ascending position; and their attachment extends to below the middle of the ventral face. (The nutlets carry away with them a "lacinula" of the style, in the manner of *Cynoglossum*.) Rotate or short hypocraterimorphous corolla, somewhat supra-basal or ventral attachment of nutlets, these

with depressed back surrounded by a wing or margin which at maturity is reflexed or revolute, and its teeth or laciniæ when present not glochidiate (although the disk is sometimes so), would appear to be the essential characters of *Omphalodes.*

Eritrichium, Schrad., was founded upon the European *Myosotis nana* of Villars, and the generic name is appropriate. Schrader gave no character except that the carpophore at maturity is "conica vel hemisphærico-conica," and the genus was first characterized by Gaudin and by Koch. The younger Reichenbach in the Icones Fl. Germanicæ notes its extreme nearness to *Omphalodes,* but distinguishes it mainly by the somewhat doubled fornices of the corolla. It really appears to be a good *Omphalodes.* Reichenbach's figures represent the short attachment of the nutlets as nearly central; that of Spenner, in Gen. Fl. Germ. Ill., as intra-basal. The oblique position of the half-grown nutlets is well shown in the recent plate in Bot. Mag. t. 5853. A full examination of the fruit and flowers of this species and the other true or dorsally appendaged *Eritrichia* convinces me that they should be referred to *Omphalodes,* from which they may be somewhat indefinitely distinguished as a section. The obviously excessive development of the genus *Eritrichium* in quite another direction began with the De Candolles in the Prodromus, was first followed by my venerated associate Dr. Torrey, was carried further by myself in Proc. Am. Acad. x. 55, &c., and was adopted by Bentham in the Genera Plantarum, but with the excision of two Candollean sections, one of them referred to *Mertensia,* the other (*Endogonia*) re-established as the genus *Trigonotis,* Stev. As I am responsible for the suppression of Fischer and Meyer's two genera, *Krynitzkia* and *Plagiobothrys,* I must now make amends by reinstating them and giving them the full development which they may rightfully claim. Although they make some near approaches to neighboring genera and to each other, yet, on the whole, they are as distinct as are most genera of *Borragineæ,* and we cannot do without them. As to true *Eritrichium,* those who may not accept its reduction to a subgenus of *Omphalodes* will probably agree to the proposed limitation of the group.

Krynitzkia, Fischer & Meyer, has the nutlets always attached by the inner side of the base, or from this upward in various degrees, even to the apex, on separation leaving a clean naked scar, or a scar narrowing into a groove, or sometimes a narrow groove only. And between these there are all gradations. The nutlets are naked and convex on the back, and otherwise wholly unappendaged, except that a few have plane-winged margins.

Anoplocaryum, Ledeb., of a single (Siberian) species, with rather the habit of *Trigonotis*, differs from *Krynitzkia* in having its smooth and erect nutlets attached *above* the base for some length by a very narrow cariniform caruncle (if it may be so called) to a conical-subulate gynobase, and the sepals in fruit are spreading.

Plagiobothrys, Fischer & Meyer, is certainly a good genus, of considerable extent and diversity, although the original character is applicable to only one species. Its essential characters are found in the insertion of the (ovate or trigonous) nutlets by a small portion of the ventral face, mostly by near the middle (sometimes nearer to the base, rarely nearer the apex), by means of a sort of caruncle, which remains on the nutlet. The fall of the ripe nutlets, which is usually tardy, leaves as many excavations or sunken areolæ on the globular, or in one species more elevated and in most of them more depressed, gynobase. The caruncle in the typical species is annular, bordering a deep and round umbilical cavity of the nutlet itself, — a character to which the generic name refers. Up to this year, however, I could find no such excavation (and evidently Bentham was in the same case); so I had ventured to assert that the character of Fischer and Meyer and of De Candolle might be incorrect. But I have now received specimens from three localities in California (one from the extreme northern border, and one from the southern part of the State), which well exhibit this character. Once made known, I have been able to verify it upon quite immature fruits of a Chilian plant from Bertero's collection. All doubtless belong to the original *P. rufescens*. I find in another Chilian species an annular caruncle, unaccompanied by any manifest excavation. The species of *Eritrichium* § *Plagiobothrys* in my Synoptical Flora, although with solid and more or less projecting caruncle, are evidently congeneric, even to *E. Kingii*, which, when mature fruit was unknown, was thought to effect a clear transition to *Krynitzkia*. *Echidiocarya Californica* and (yet more obviously) *E. ursina* are also of the genus, differing only in the more salient or stipitiform and indurated caruncle. This leaves *Echidiocarya* with a single species, of very peculiar fruit.

Microula, Benth., of a single species from Tibet, in Strachey and Winterbottom's collection, essentially accords with a section of *Plagiobothrys*, which has glomerate inflorescence and high insertion of nutlets by means of a soft caruncle. But in *Microula* this is small and somewhat evanescent. The "subsessile glochidia," as they are called in the Flora of British India, are so minute and sparse that they need hardly be taken into account; but the genus may perhaps be kept up, partly on geographical considerations.

Bothriospermum, Bunge, as arranged and characterized by Bentham in the Genera Plantarum, would appear to have essentially the same carpological structure as the typical *Plagiobothrys*, and therefore to supersede the latter. But this comes from one of the very rare oversights of the late Mr. Bentham, who, unmindful of the correct description by Bunge, and afterwards by De Candolle and by Maximowicz, mistook the ventral false umbilicus for the areola of insertion, which is basal. The mistake remains uncorrected in the Flora of British India.

The conclusions now arrived at lead to the following re-arrangement of the American species which are thereby affected.

OMPHALODES, Tourn.

Corolla rotata vel brevissime hypocraterimorpha. Stamina inclusa. Nuculæ adscendentes vel subhorizontales, intus (aut supra medium aut versus basim) gynobasi pl. m. elevatæ affixæ, dorso depressæ vel complanatæ, ala nunc integra nunc dissecta (rarius evanida) retrocurva vel revoluta (dentibus laciniisve haud glochidiatis) circumdatæ.

§ 1. EUOMPHALODES. Nuculæ pl. m. obcompressæ, intus haud carinatæ, pericarpio alaque sat tenuibus. — Gerontogeæ, sequentibus alienis facie *O. vernæ* pæne similibus exceptis.

O. ALIENA, Gray in Hemsl. Bot. Biol. Centr.-Am. ii. 377. Laxe hirsuta, brevicaulis; foliis insigniter cordatis longe petiolatis; racemis elongatis ebracteatis; pedicellis gracilibus, fructiferis deflexis vel recurvis; corolla cærulea; nuculis suberectis ala lata orbiculata margine breviter multidentata radiato-expansa demum (saltem fl. inferiorum) plicato-retroflexa, areola insertionis centrali obscura; cotyledonibus obovatis; gynobasi pyramidata demum angusta. — Northern Mexico at Monterey, Nuevo Leon, coll. *Palmer*, 893. Geography to the contrary notwithstanding, this must be accepted as a true *Omphalodes*, in essential character as well as in habit. Even if the wing of the nutlets were always explanate, this is no more so than in *O. amplexicaulis*, and the gynobase is hardly higher or narrower. Moreover, in the nutlets of some of the lower and consequently older blossoms, the wing is completely folded backward upon itself. As the body in these is hispidulous while the upper ones are almost glabrous, I had suggested that the fruit was probably dimorphous, and Mr. Hemsley in his account has mentioned this. But perhaps it is only a difference in age. When it falls away from the gynobase, the convex ventral surface shows no scar, or only faint marks of attachment about the middle; when younger,

the attachment seems to be from "just above the base to the apex" of the body, as Mr. Watson describes it in the account of Palmer's collection (Proc. Am. Acad. xviii. 121). There are indications that, in separating, a minute lacinula of the style is sometimes carried away, as in most of the European species. In Hemsley's description this and the following species are said to be annuals. Our specimens are not decisive in this respect; they appear rather to denote a perennial growth from slender running rootstocks.

O. CARDIOPHYLLA, Gray, l. c. Præcedenti similis; pedicellis plerisque oppositifoliis vel extra-axillaribus, paucis in racemum fere ebracteatum digestis; "corolla alba"; nuculis calycem subpatentem haud superantibus crassioribus brevi-ovalibus basim versus gynobasi pyramidata parum elevata adfixis, dorso sursum spectante ala mox retroflexa in dentes elongato-subulatos multipartita circumdato; cotyledonibus orbiculatis. — Northern Mexico, in mountains near Saltillo, coll. *Palmer*, 894. — Closely related as this species is to the foregoing, its nutlets in structure, insertion, and all but the thinner and softer texture, are very much like those of the original *Eritrichium*.

§ 2. ERITRICHIUM. (*Eritrichium*, Schrad. Diss. Asperif., Gaudin, Koch, Reichenb. Ic. Fl. Germ.) Nuculæ dorso sursum oblique spectante tantum complanatæ, intus carinatæ, pericarpio dentibusque subcartilagineis. — Amphigææ, alpinæ vel montanæ, nanæ, perennes.

* Amphigea alpina et arctica, albo-villosa.

O. NANA, cum var. ARETIOIDES et var. CHAMISSONIS. *Eritrichium nanum*, Schrader, cum vars. *aretioides* et *Chamissonis*, Herder in Radde; Gray, Syn. Fl. ii. 190. To the synonymy add the excellent figure, from the European plant, of Hook. f. Bot. Mag. t. 5853, which well exhibits the oblique position of the forming nutlets.

* * Boreali-Americana, cano-strigosa, nuculis calvis!

O. HOWARDI. *Cynoglossum Howardi*, Gray, Syn. Fl. ii. 188. Dense cæspitosa, pube sat molli argenteo-incana; foliis caudiculorum confertissimis lineari-spathulatis, caulium floriferorum brevium linearibus sparsis; cyma aut dichotoma aut simplici racemiformi pauciflora parce bracteata; sepalis linearibus corollæ cœruleæ lobis paullo brevioribus; nuculis nitidis dorso oblique truncatis exalatis, sed disco dorsali plano ovato acutiusculo angulato-marginato aut lævi aut minute papuloso et puberulo. — Rocky Mountains in Montana, *Winslow J. Howard*, coll. in flower only, about the year 1866; on Mount St. Helena, Montana, Canby, 1883, with mature fruit; Cascade Mountains, Washington Terr., *Frank Tweedy*, 1882, in flower. In Proc. Am. Acad.

xvii. 225, I had too confidently guessed this little plant to be the *Cynoglossum ciliatum* of Douglas, which is possibly a congener, but for the present is taken for an *Echinospermum.* But Mr. Canby, by collecting the fruit, has made it clear that the present plant is, as its habit would denote, a congener of *O. nana.* As far as known, the present species has the edentate nutlets of *O. rupestris*, especially of the form which Maximowicz named *Eritrichium Maackii;* but from its analogy with that species we may expect varieties with more or less pectinate teeth on the angled border.*

KRYNITZKIA, Fisch. & Meyer, ampliata.

Corolla rotata vel hypocraterimorpha, tubo brevi calycem (fructiferum erectum vel vix patentem) rarissime superante. Stamina inclusa. Nuculæ erectæ et rectæ, nudæ, rarove angulis lateralibus patenti-alatis, intus basi tantum vel altius vel ad apicem usque gynobasi nunc parum nunc longe elevatæ adfixæ; areola pl. m. impressa vel sulco insertionis prorsus nuda. — Herbæ annuæ vel paucæ perennes, plerumque Occidentali-Americanæ, floribus albis sæpissime parvis. — *Krynitzkia*, Fisch. & Meyer, Ind. Sem. Hort. Petrop. vii. (1841) 52. *Krynitzkia* & *Eritrichium* sect. v.–vii., A. DC. Prodr. x. 128–134. *Eritrichium* § *Krynitzkia*, § *Eueritrichium Myosotidea*, & *Antiphytum*, Gray, Proc. Amer. Acad. x. 55, & Syn. Fl. ii. 191–197, 199.

§ 1. Amblynotus. Nuculæ (lithospermoideæ) *cartilagineæ* vel *crustaceæ*, ovatæ, dorso (una excepta) rotundatæ, intus basi aliquandoque paullo altiore gynobasi convexæ vel depresso-pyramidatæ adfixæ.

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* O. rupestris (*Myosotis rupestris*, Pall., *Eritrichium rupestre*, DC.) would be the proper name of this N. Asiatic species, which, according to Maximowicz (Diagn. Dec. xi. 546), includes also *E. pectinatum*, DC., as a form with pectinately fringed border to the nutlets. Herder keeps up two species, but apparently refers too many Himalayan forms to the latter.

O. villosa. *Eritrichium villosum*, A. DC. Prodr. x. 126, cum syn. *E. latifolium*, Ruprecht? Herder's reference to this as found on our Rocky Mountains was caused by taking the name from S. Watson, who (in Bot. King, 240) followed Hook. f. in his Memoir on Arctic Plants. Some forms of *O. nana* do indeed much resemble *O. villosa.*

O. Schrenkii = *Echinospermum rupestre*, Schrenk in "Bull. Acad. Petrop. ii. 194," & DC. Prodr. x. 140. This has the habit of *O. rupestris*, and, although anomalous, should go with it rather than into *Echinospermum.* The nutlets are quite erect, indeed, but their narrow wing is strictly turned over upon the back, and the few and short teeth which it bears are not at all glochidiate.

* Species Boreali-Asiatica, facie *Omphalodium* § *Eritrichii* regionis, perennis: nuculæ læves, dorso rotundato carina obsoleta, ventre carina acuta instructa, areola insertionis rotundata. — *Eritrichium* § *Amblynotus*, A. DC. Prodr. x. 128.

K. OBOVATA. *Myosotis obovata*, Ledeb. *Eritrichium obovatum*, A. DC. l. c.

* * Species Californica, annua, *Krynitzkiis typicis* facie referens: nuculæ lævissimæ, nitidæ, dorso carina prominula ventre sulco angustissimo percursæ, areola insertionis brevi-lineari sulciformi a basi ad quartem partem attingente.

K. LITHOCARYA, Greene, ined. — Lakeport, Lake Co., California, 1884, *Mrs. Layne-Curran.*

* * * Species Texano-Mexicanæ, anomalæ, ramosæ, caulibus basi pl. m. indurata diu persistente vix perennantes: nuculæ turgide ovatæ, dorso latæ omnino rotundatæ, papulis undique asperatæ, intus acute carinatæ, basi parum protuberante areola rotundata adfixæ. — *Antiphytum*, A. DC. pro parte; Gray, Proc. Am. Acad. x. 54, & Syn. Fl. ii. 199.

Antiphytum, as founded by De Candolle upon Moçino's drawing of a Mexican species, is utterly obscure; as propounded by him in Meissner's work it is apparently a good genus for Brazilian species with opposite leaves, for which Bentham re-establishes it. But the following species, as Bentham indicated, must be allowed to fall into the present genus. Although somewhat peculiar in habit, it comes well into the present section as now extended.

+ Sat elatæ, paniculatæ.

K. HELIOTROPIOIDES. *Antiphytum heliotropioides*, A. DC. Prodr. x. 122; Gray, l. c. *Eritrichium heliotropioides*, Torr. Bot. Mex. Bound. 140.

K. FLORIBUNDA. *Eritrichium floribundum*, Torr. l. c. *Antiphytum floribundum*, Gray, l. c. — Corolla fauce nuda.

+ + Humilis, condensata; foliis parvis.

K. PARRYI. *Antiphytum Parryi*, Watson, in Proc. Am. Acad. xviii. 122. — Between San Antonio, Texas, and San Luis Potosi, Mexico, coll. *Parry*, no. 618, in part.

§ 2. MYOSOTIDEA. Nuculæ basi intus areola brevissima vel brevi gynobasi depressæ vel parum elevatæ adfixæ, pl. m. ovatæ, rugosæ, opacæ, parum induratæ, ventre sæpius dorso quandoque carinatæ. Herbæ humiles, sæpius tenellæ. — *Eritrichium* § *Eueritrichium Myosotidea*, Gray, l. c.

* Annuæ.

+– Sæpius diffusæ, parvifloræ; corolla calycem parum superante, limbo vix ultra lineam lato; sepalis quandoque post anthesin folioso-ampliatis.

K. PLEBEIA. *Lithospermum plebeium*, Cham. & Schlecht. *Eritrichium* (*Rutidicaryum*) *plebeium*, A. DC. Prodr. — Aleutensis: caules laxi ad apicem usque foliati.

K. CALIFORNICA. *Myosotis Californica*, Fisch. & Meyer. *Eritrichium Californicum*, DC. Nuculæ ovato-oblongæ, rugis obtusis parcis notatæ, læves vel scabriusculæ. — In the alkaline wet soil which this species affects, the herbage is apt to become succulent and the calyx accrescent. Such forms especially pass into the notable

Var. SUBGLOCHIDIATA. Nuculis scabridis vel subtuberculatis aut parce aut insigniter hirtellis, setulis sæpe fasciculatis (nunc basi in fasciculum coalitis) apice vel simplicibus vel furcatis vel penicillatis etiam subglochidiatis. — *Eritrichium Californicum*, var. *subglochidiatum*, Gray, Syn. Fl. ii. 191. The specimens of Watson and others from the Great Basin and eastward are mostly of this variety; but it also occurs in the valley of the Sacramento, &c., both in succulent and unaltered forms.

+– +– Laxæ, corollæ limbo lin. 1–2 lato, nuculis asperato-rugosis.

K. TRACHYCARPA. Erecta vel diffusa, facie præcedentis; foliis inferioribus sæpe oppositis; nuculis late ovato-trigonis rugis crebris reticulatis acutis hinc inde muricatis pl. m. asperatis nunc inter rugas sæpius granulatis; areola insertionis oblonga. — California in Sonoma Co., *Brewer*, and San Joaquin Valley, *Greene*. I have this in a depauperate form from a Chilian collection made near Valparaiso in 1856 by Dr. Harvey, and in a tall form with opposite leaves, quite to the inflorescence in Reed's Chilian collection, named at Kew *Eritrichium uliginosum*, Philippi. Wherefore it may be suspected to be the *Lithospermum muricatum* of Ruiz & Pavon (*Eritrichium? muricatum*, A. DC.), and probably it may have other specific names; none of them, however, can be safely adopted. It is one of the species which connect the present section with *Eukrynitzkia*.*

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* The South American species of this section seem to be few, but under several names. They should be worked up by a botanist having access to most of the originals.

K. LINIFOLIA (*Anchusa linifolia*, Lehm., *A. oppositifolia*, HBK. in the same year, *Antiphytum linifolium*, DC., and *Eritrichium linifolium*, Weddell) is the Andean species with wholly or chiefly opposite leaves and radicant bases of the tufted

+ + + Floridæ, corollæ limbo ratione calycis majusculo valde rotato-explanato, fornicibus conspicuis; nuculis rugosulis.

K. Chorisiana. *Myosotis Chorisiana*, Cham. & Schlecht. *Eritrichium Chorisianum*, DC., Gray, Syn. Fl. ii. 191, cum syn. — Pube parca sæpius adpressa; floribus laxe pedicellatis.

K. Scouleri. *Myosotis Scouleri*, Hook. & Arn. *Eritrichium Scouleri*, A. DC. l. c.; Gray, l. c., cum syn. — Facie præcedentis, floribus in spicis strictis subsessilibus.

K. Cooperi. *Eritrichium Cooperi*, Gray, Proc. Am. Acad. xix. 89. — Facie *K. Scouleri*, magis diffusa vel decumbens, setis patentibus hispida. — In the Mohave district, *Cooper*, *Parish*.

* * Perennans, caulibus decumbentibus basi repentibus radicantibus; pube villosa sat molli; corollæ limbo rotato-patente lin. 3–4 lato; nuculis fere *K. Californicæ*, sed areola insertionis prorsus introrsa ovato-lanceolata gynobasi oblongo-pyramidatæ adfixæ.

K. mollis. *Eritrichium molle*, Gray, Proc. Am. Acad. xix. 89. — Wet borders of ponds, Sierra Valley, California, *Lemmon*. A rougher form from near Visalia, *Congdon*. A transition from the present section to *Eukrynitzkia*. The scar usually extends up to nearly one third the length of the ventral face, and the gynobase is correspondingly high; but this varies somewhat, and in Congdon's specimen it is shorter.

§ 3. Eukrynitzkia. Nuculæ (nunquam rugosæ) angulo vel sulco ventrali ab ima basi nunc fere ad medium nunc apicem usque gynobasi elevatæ adfixæ, dorso convexo nec carinato nec angulato, lateribus obtusis rarove angulato-acutis nunquam marginatis: calyx fructifer erectus vel clausus: corolla parva, tubo brevi calycem haud superante, basi exannulato, fauce aut nuda aut fornicibus haud exsertis instructa. — Herbæ annuæ, floribus plerumque sessilibus scorpioideo-spicatis. — *Eritrichium* § *Krynitzkia*, div. *Eukrynitzkia*, Gray, l. c.

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stems. It must include *Eritrichium pygmæum*, Weddell (*Anchusa*, HBK.), and apparently a part of his *E. humile*, such as the var. *congestum*, Mandon's no. 381, to which Weddell's figure answers, except as to the fruit, and which is certainly not Brotero's no. 445, of Chili. The nutlets of *K. linifolia* are attached by an oval or barely oblong scar, and the back is coarsely reticulate-rugose, not at all "granulate-tuberculate."

K. tenuifolia, the "*Eritrichium tenuifolium*, Schlecht." of Lechler's Pl. Chilenses, no. 255, which has nutlets strictly of this group, must, from habitat and character, be the *Eritrichium humile*, var. *capillatum* (misprinted "*capitatum*") of Gay, Fl. Chil., which Weddell refers to as different from *E. humile*. It is quite uncertain what *Myosotis humilis*, Ruiz & Pav., an annual, can be, and what is Lehmann's, described as with a perennial and fusiform fibrillose root.

* Holocalyx, i. e. calyx fructifer non circumscissus, basi ipsa vel pedicello brevissimo intermediante rhachi pl. m. articulatus, haud raro cum fructu incluso secedens.

+ *Costatæ, Cismontanæ:* sepala nunquam angustissima, costa valida rigida, fructifera in prioribus insigniter incrassata percursa: nuculæ sæpissime opacæ, areola intrabasali (*K. Texana* excepta) manifesta: herbæ diffuso-ramosæ, hispidæ, sæpius asperæ.

++ *Hetero-* vel *Monocaryæ:* calyx fructifer inferne arcte clausus, costis insigniter cartilagineo-incrassatis.

K. crassisepala. *Eritrichium crassisepalum*, Torr. & Gray, Pacif. R. Rep. ii. 171. — Spicæ inter flores bracteatæ. Calyx fructifer in pedicello brevissimo etiam indurato diu persistens. Nuculæ ovatæ, acutæ, vix ultra medium gynobasi angusto-pyramidatæ adfixæ, tres dorso papilloso-muriculatæ et areola oblongo-lanceolata excavata insertæ; una major, lævis, diu persistens. — This species extends from the Saskatchewan to New Mexico.

K. Texana. *Eritrichium Texanum*, A. DC. Prodr. x. 130. — Elatior, spicis demum laxis plerumque ebracteatis. Calyx fructifer angustus costis angustioribus, subsessilis, maturitate fructu incluso secedens. Nucula solitaria (3 abortientibus), sat magna, parum meniscoidea, creberrime minutimque puncticulata, cæterum lævis, ventre a basi fere ad medium carina tenui gynobasi adfixa, diu persistens, delapsa basi lacera.

++ ++ *Homocaryæ:* nuculæ 4 fertiles conformes, gynobasi angustiori adfixæ, læves, ovato-acuminatæ, vix lineam longæ, sulco ventrali ima basi in areolam paullo excavatam subtriangularem repente dilatato: calyx fructifer (lin. 2 longus) minus clausus, setis pungentibus hispidus, costis prominentibus sed minus crassis: spicæ basi tantum bracteatæ vel ebracteatæ.

K. Pattersoni. Humilis, a basi diffusa; foliis angusto-spathulatis seu linearibus; sepalis lineari-lanceolatis costa demum prominente: nuculis a basi ad medium (vel paullo ultra) gynobasi subulato-pyramidatæ adfixis, una quandoque magis persistente. — At the base of the Rocky Mountains in Colorado; coll. *H. N. Patterson*, 1875, *J. D. Hooker* and *A. Gray*, 1877. A species till now overlooked, connecting the following with the preceding group.

K. Fendleri. Erectus, subpedalis, paniculato-ramosus, rigidulus; foliis linearibus; sepalis fructiferis angusto-linearibus; nuculis sursum magis attenuatis fere ad apicem usque gynobasi angusto-subulatæ adfixis. — Along the eastern base of the Rocky Mountains, from the

Saskatchewan district (Hand Hills, *Macoun*) to Colorado, Northern New Mexico, and apparently in Arizona; coll. *Fendler*, *Hall*, *Parry*, *Vasey*, *Porter*, *Rusby*, &c. It has been unwarrantably confounded with *K. leiocarpa*, &c.

+ + *Typicæ, Transmontanæ, Leiocaryæ:* nuculæ lævissimæ, nitidæ, acutæ vel acuminatæ, pericarpio sat tenui, sulco ventrali tenui percursæ, basi haud vel minime areolatæ, gynobasi angustæ adfixæ: sepala angusta, costa nunc prominula nec incrassata instructa: herbæ diffusæ vel erectæ, graciles, calycibus setoso-hispidis.

++ *Eremocaryæ:* nucula solitaria (rarissime 2, cæteris abortientibus), angusta, acuminata, inferne triente parte tantum gynobasi brevi angustæ adfixa, itaque sursum longius libera (*Amblynoti* modo), areola intrabasali vix ulla: herbæ graciles, erectæ; spicis sæpius conjugatis ternisve ebracteatis, calycibus fructiferis arcte sessilibus rhachi plerumque adpressis.

K. OXYCARYA. *K. leiocarpa*, Benth. Pl. Hartw. 326, non Fisch. & Meyer. *Eritrichium oxycaryum*, Gray, Proc. Am. Acad. x. 58, & Syn. Fl. ii. 193. *Myosotis flaccida*, Dougl. in Lehm. Pugill. ii. 22, & Hook. Fl. ii. 82; Hook. & Arn. Bot. Beech. 369. Pube brevi strigulosa arcte adpressa subcinerea; caule sæpius stricto ultrapedali; foliis linearibus vel lineari-spathulatis; calyce fructifero (circa lin. 2 longo) segmentis lineari-filiformibus crassiusculis, versus basim setis crebris *deflexis* (validis haud pungentibus, apice attenuato debili nunc incurvo) hispidissimis, superne nudiusculis vel setis brevioribus instructis; nucula majuscula subtereti ex ovata longius acuminata quasi rostellata. — Not rare from S. California to Washington Territory. When we did not possess specimens north of California, I referred the original *Myosotis flaccida*, described by Lehmann, to *K. leiocarpa*, partly because of the "nuces 4" in the description. But I now learn that original specimens from "barren grounds in the interior of the Columbia" have solitary nutlets, and are of this well-marked species.

K. MICROSTACHYS, Greene in herb. Setis breviusculis patentibus pl. m. hirsuto-hispida; caule ramoso semipedali ad bipedalem; foliis aut angusto- aut lato-linearibus; calyce fructifero lineam ad sesquilineam longo setis subpungentibus longis patentissimis (nec deflexis) hispido vel hispidissimo, segmentis minus attenuatis; nucula ovato-lanceolata sensim acuminata ventre parum complanata sulco manifesto ima basi subfurcato percursa. — California, near Tejon, *Xantus*, no. 84, 86 (*K. leiocarpa*, & *Eritrichium?* spec., Gray, Jour. Bost. Nat. Hist. Soc. vii. 147); Los Angeles, *Nevin;* San Diego, *Pringle* (the

least hispid and narrowest-leaved form, nearly approaching the preceding species, and distributed as *Eritrichium oxycaryum*, coll. April 6, 1882); Colusa Co., 1884, *Mrs. Layne-Curran*, a depauperate and very slender form. The spreading bristly hairs sometimes abound on the stems as well as the leaves.

++ ++ *Eutypicæ:* nuculæ sæpius 4 fertiles, gynobasi angustæ elevatæ adfixæ, haud areolatæ,

= Intus tota longitudine sulco tenui basi nec furcato nec in areolam explanato percursæ: herbæ humiles, laxæ vel diffusæ, piloso-hispidæ; foliis lineari- vel oblongo-spathulatis; spicis cymæ simplicis vel bipartitæ laxifloris vel interruptis basi sæpius foliatis, vel floribus primariis alaribus et pseudo-axillaribus; calycibus fructiferis lin. 2 longis; corollis minimis.

K. LEIOCARPA, Fisch. & Meyer, Ind. Sem. 1841, 52; A. DC. Prodr. x. 134. *Echinospermum leiocarpum*, Fisch. & Meyer, op. cit. 1835, 36. — Nuculæ parvæ (vix ultra semilineam longæ) ovatæ, acutæ, paullo obcompressæ, fere tota longitudine sulci recti gynobasi subulatæ adfixæ. — Western California, from Monterey (where Dr. Parry collected a low and rather stout form, with oblong leaves) northward, probably to Oregon and Washington Territory. But the only determinable specimens in our herbarium, except early cultivated ones, directly or indirectly from the originals raised at St. Petersburg, were collected by Dr. Kellogg on the Californian coast, either near San Francisco or farther northward. Under the name of *Eritrichium leiocarpum*, first used by S. Watson in Bot. King Exped. 244 (who, however, did not collect the genuine plant), three or four smooth-fruited species have been confounded. These may now, upon the re-establishment and extension of the genus *Krynitzkia*, be distinguished mainly by characters of the fruit, which seem to be good, although rather fine. In the present and the following species the slender ventral groove by which the nutlet is attached runs to its very base, without the furcation of the next succeeding species, and without any expansion into a scar.

K. AFFINIS. Nuculæ lineam vel ultralineam longæ, turgidæ, subutriculatæ (pericarpio tenuiori), ad medium usque gynobasi tenuiter pyramidatæ adfixæ, sepalis lineari-lanceolatis aut paullo aut dimidio breviores. — On the eastern side of the Sierra Nevada, California to Washington Terr. and Idaho. The specimens now in hand are: E. side of the Cascades near lat. 49°, *Lyall*, 1860. Beaver Cañon, Idaho, *Watson*, 1880. Falcon Valley, Washington Terr., *Suksdorf*,

1880. Oregon, without locality, *Howell.* Near Donner Lake, *Torrey*, 1865. Strong's Cañon, near Truckee, *Mrs. Layne-Curran*, 1884. It has, with others, passed under the name of *Eritrichium leiocarpum*, and in appearance is most like the original *Krynitzkia.*

= = Nuculæ faciebus interioribus fere planis exteriori convexiuscula pl. m. trigonæ, angulo interiori sulco tenui juxta basim divaricato-furcato sed clauso: herbæ erectæ, sæpe pedales; spicis cymæ bene evolutæ (simplicis vel conjugatæ) ebracteatis.

K. Torreyana. *K. leiocarpa*, Torr. Bot. Mex. Bound. 142, at least in part. *Eritrichium leiocarpum*, Watson, Bot. King Exped. 244, in large part; Gray, Proc. Am. Acad., & Syn. Fl. ii. 194, in large part and by char., excl. syn. Fisch. & Meyer and Dougl. — Hirsuto-hispida; calyce (præter pubem villosam) setis pungentibus patentissimis hispido, fructifero sepalis sursum attenuatis; corollæ pl. m. exsertæ limbo lin. 1–2 lato; nuculis (lineam longis) ovatis acutis usque ad medium tantum gynobasi subulato-pyramidatæ adfixæ. — Nearly throughout California, and east to Nevada and southwestern parts of Idaho. This species, now distinguished from its allies, may well bear the name of Dr. Torrey, who was an early investigator of this group, and who himself more than once collected it, whether or not it be the one he had mainly in view as *K. leiocarpa* in his references in Bot. Mex. Boundary, &c. But what he so called in Pacif. R. Rep. iv. 124 is *K. oxycarpa*. The calyx varies in length, &c., evidently passing into

Var. calycosa. Forma sæpius robusta, congestiflora; sepalis calycis fructiferi pl. m. elongato-attenuatis lin. 2–3 longis rigidulis, costa validiori. *Eritrichium leiocarpum*, Watson, Bot. King Exped. l. c., quoad "calyx-lobes linear, becoming much elongated." — E. Humboldt Mountains, Nevada, *Watson*, and a form approaching it, coll. in Nevada by *J. D. Hooker* and *A. Gray*, 1872. Lake Co., California, *V. Rattan*, 1884, a form seemingly abnormal by the capitate-congested inflorescence and much prolonged sepals.

K. Watsoni. Minus hispidula, gracilis; sepalis calycis fructiferi vix lin. 2 longi parce setoso-hispidi lanceolatis parum attenuatis; corolla parva; nuculis (lineam longis) angustis subtriquetris circumscriptione fere oblongo-lanceolatis tota fere longitudine gynobasi filiformi-subulatæ adfixis. — Wahsatch Mountains, Utah, at 6,000 feet, *S. Watson*, 1869, a part of *Eritrichium leiocarpum*, Bot. King Exped. l. c.

++ ++ ++ *Asperulæ Anisocaryæ:* nuculæ sat angustæ, punctis creberrimis scabræ, sæpius heteromorphæ, ventre sulco inferne ampliato

fere tota longitudine gynobasi subulatæ adfixæ: herbæ diffusæ, parvifloræ; spicis bene evolutis ebracteatis; calycibus fructiferis (haud ultra semilineam longis) setis validis divaricatis pungentibus armatis.

K. ANGUSTIFOLIA. *Eritrichium angustifolium*, Torr. Pacif. R. Rep. v. 363 & Bot. Mex. Bound. 141. Humilis, demum ramosissima diffusa; foliis linearibus; setis calycis fructiferi eo vix brevioribus; nuculis scabridis subtrigonis, sulco infra medium vel juxta basim subdeltoideo-ampliato, aut fere homomorphis aut sæpius 2 vel 3 triangulari-ovatis et 1 vel 2 longioribus angustioribus circumscriptione ovato-lanceolatis, brevioribus quandoque abortivis. — This species is characteristic of the Mohave Desert, but it extends into Arizona as far as to Tucson. And from insufficient specimens sent in 1884 by Suksdorf, from Morgan's Ferry, Yakima River, it would appear to have made its way northward even to Washington Territory.

K. DUMETORUM, Greene in litt. Laxe ramosa, in dumetis quasi scandens; foliis ramealibus oblongis seu lanceolatis papilloso-hispidis; sepalis fructiferis lanceolatis; nuculis angustis acuminatis hirtello-scabris heteromorphis, 3 oblongo-lanceolatis subteretibus ventre sulco aperto infra medium latiore, una multo majore ovato-lanceolata in gynobasi subulata persistente calycis segmentis 2 ultra medium in unicum coalitis arcte fulcrata! — Southern California, at the Tehachapi Pass, *Mrs. Layne-Curran*, coll. 1884. The examination of the single fruiting branch received shows this to be a peculiar species, of evident relationship to the foregoing. The fruiting calyx is distorted or made gibbous at base by the enlargement of the persistent akene (of fully a line in length), round which the two united subtending sepals are half wrapped. More specimens are desirable for ascertaining if these peculiarities are constant.

++ ++ ++ ++ *Trachycaryæ Ebracteatæ:* nuculæ homomorphæ, ovato-trigonæ, dorso præsertim papillis acutis muricatæ vel scabratæ, ad apicem vel subapicem usque sulco longo basi aut furcato clauso aut in areolam pl. m. dilatato gynobasi subulatæ adfixæ; herbæ plerumque erectæ, hispidæ; spicis fructiferis rite evolutis ebracteatis; calycibus setis pungentibus patentissimis hispidis.

= Calycis fructiferi sepala 4–2 lin. longa, attenuato-linearia, costa prominula percursa, nuculas acutas vel acuminatas longe superantia.

a. Herbæ insigniter villoso-hispidæ, id est setis pilisque gracillimis plerumque albis barbatæ.

K. BARBIGERA. *Eritrichium barbigerum*, Gray, Syn. Fl. 194. Sat robusta, a basi ramosa; spicis elongatis. Calyces fructiferi majusculi, lin. 3–4 longi, subpedicellati, sepalis haud raro apice parum dilatatis. Corolla limbo lin. 1 vel 2 diametro. Nuculæ (1–2 vel 2–3 rarissime 4 fertiles) ovatæ, apice subacuminatæ, scabro-muricatæ, griseæ, sulco basi in areolam parvam triangularem desinente nec in furcam producto. — We have it only from the southern parts of California and the adjacent western part of Arizona. This and the two following species are either confluent or hard to define.

b. Sepala fructifera minora (lin. 2–3 longa), setis rigidis albidis seu flavescentibus hispida, cum vel sine pube brevi: corolla limbo lin. 1–3 lato: caulis passim 1–2-pedalis.

K. INTERMEDIA. *Eritrichium intermedium*, Gray, Proc. Am. Acad. xvii. 225. Nuculæ oblongo-ovatæ, pl. m. acuminatæ, crebre asperato-muricatæ, sulco latiusculo nunc fere ad apicem aperto. — Only in the southern part of California, from Los Angeles and San Diego to the Mohave district. There is a small-flowered and a larger-flowered form.

K. AMBIGUA. *Eritrichium muriculatum*, Torr. in Wilkes Exped. xvii. t. 13. *E. angustifolium*, Watson, Bot. King Exped. 241, non Torr. *E. muriculatum*, var. *ambiguum*, Gray, Syn. Fl. ii. 194. Nuculæ deltoideo-ovatæ, pl. m. acuminatæ, scabrido-muriculatæ, sulco sæpius inferne aperto basi divaricatim furcato. — Not uncommon from Southern California to Oregon, the interior of Washington Territory, Nevada, and apparently N. Arizona.

= = Calycis fructiferi ovalis vel oblongi sepala lanceolata, sesquilineam vel haud ultra lin. 2 longa, nuculas minus superantia; costa obscura, setis fulvis.

K. MURICULATA. *Myosotis muricata*, Hook. & Arn. Bot. Beech. 369. *Eritrichium muriculatum*, A. DC. Prodr. x. 132; Gray, l. c. Sat robusta, 1–2-pedalis, vel minor gracilior; cymis rite evolutis sæpius 2–3-radiatis, spicis densifloris; corollæ limbo lin. 1–2 lato; nuculis lineam longis circumscriptione deltoideo-ovatis obtusis vel acutiusculis scabro-muricatis, sulco tenui basi divaricato-furcato plerumque clauso. — Nearly throughout California, extending to Washington Territory. The plant of Douglas, on which the species was founded by Hooker and Arnott, is one of the stouter forms, too young for well making out the fruit. In Proc. Am. Acad. x. 59, I inadvertently took it to belong to *Plagiobothrys canescens*.

K. Jonesii. Pedalis, gracilis; caule stricto cum ramulis brevibus spicigeris sæpius plurimis lateralibus racemoso-paniculatis; foliis parvis angusto-linearibus; calycibus fructiferis haud ultra sesquilineam longis setis paullo brevioribus armatis; nuculis ovato-trigonis obtusis (semilineam longis) aspero-muriculatis, sulco ventrali basi furcato clauso; stylo crassiusculo breviter exserto. — Bay of Monterey, California, at Soledad and at Santa Cruz, *Marcus E. Jones*, 1882. Lower California near the U. S. boundary, *C. R. Orcutt*, no. 1022, 1884. — Differs from the preceding, not only in the smaller size of the parts, but in the usual character of the inflorescence. Resembles rather Bertero's no. 1157 of Chili, *K. clandestina* (*Eritrichium clandestinum*, A. DC., &c.); but it has different nutlets and no cleistogamous flowers.

= = = Calyx fructifer vix lineam et nuculæ ⅓-lineam longæ.

K. micromeres. *Eritrichium micromeres*, Gray, Proc. Am. Acad. xix. 90. *E. angustifolium*, Gray, Proc. Am. Acad. v. 165, non Torr., &c. Subpedalis, hispidula, erecta, diffuso-ramosa; foliis parvis; spicis filiformibus; floribus minimis; sepalis lanceolatis obtusiusculis; nuculis ovato-trigonis acutiusculis acutangulis nitidulis dorso muriculatis, faciebus internis sæpius concavis lævibus, sulco ventrali basi subito dilatato. — California, at Santa Cruz, *Marcus E. Jones*, 1881. Lower California at Cape San Lucas, *Xantus*, 1860.

++ ++ ++ ++ ++ *Trachycaryæ Sparsibracteatæ:* nuculæ breves, latotrigonæ, dorso papillis sparsis muricatæ, intus areola sat magna triangulari gynobasi pyramidatæ acutæ adfixæ, supra medium liberæ, carina parum sulcata: stylus vix exsertus: spicæ pl. m. bracteatæ: calyx fructifer vix ultra-lineam longus, setis haud pungentibus breviusculis hispidus; sepalis lanceolatis, costa obscura: corolla minima: herbæ diffuso-ramosæ, humiles, Texano-Mexicanæ; foliis parvulis plerumque linearibus.

K. pusilla. *Eritrichium pusillum*, Torr. & Gray, Pacif. R. Rep. ii. 171. Hispidula, parvula, a basi diffusa; spicis elongatis densifloris bracteis minimis hinc inde instructis; nuculis nitidulis haud semilineam longis, dorso papilloso convexo, angulis lateralibus acutis, faciebus internis arcte concavis lævissimis, areola intrabasali deltoidea parum excavata. — Fine specimens of this well-marked species have been recently collected at Fort Davis, S. W. Texas, by *Dr. Girard.*

K. ramosa. *Lithospermum ramosum*, Lehm. Asperif. 328. *Myosotis albida*, HBK. Nov. Gen. & Spec. iii. 91. *Eritrichium ramosum*, A. DC. Prodr. x. 132. *E. hispidum*, Buckley in Proc. Acad. Philad.

1861, 492; Gray, Proc. Am. Acad. x. 59, & Syn. Fl. ii. 195. *E. heliotropioides*, Torr. Bot. Mex. Bound. 140, pro parte, excl. syn. *Amsinckiæ* spec., Benth. Pl. Hartw. no. 157. — Hispida, e caule sæpius erecto solute ramosa; spicis folioso-bracteatis, fructiferis laxifloris; nuculis (⅝ lin. longis) opacis obtuse papillatis lateribus rotundatis, areola insertionis triangulari ampla excavata. — As this species extends well into Mexico, and accords with both Lehmann's and Kunth's accounts (published in the same year), the specific name under which the former found it in Willdenow's herbarium is here restored. [This identification is confirmed by Dr. Eichler, through a reference to the original specimens of Humboldt in the Berlin herbarium.]

++ ++ ++ ++ ++ ++ *Crebribracteatæ*, parvulæ, pube tenui: nuculæ ovato-lanceolatæ, acuminatæ (semilineam longæ), haud angulatæ, aut læves nitidulæ, aut minutim papilloso-scabræ et opacæ, sulco angustissimo inferne parum latiori tota longitudine gynobasi filiformi seu tenuiter columnari adfixæ: stylus sæpius incrassatus: sepala lato-lanceolata, fructifera lineam longa, haud setosa, costa obscura: spicæ breves, condensatæ, congestæ, bracteis foliosis flores superantibus.

K. MICRANTHA. *Eritrichium micranthum*, Torr. Bot. Mex. Bound. 141. Pube brevi griseo-hirsuta, limbo corollæ vix lineam lato.

Var. LEPIDA. *Eritrichium micranthum*, var. *lepidum*, Gray, Syn. Fl. ii. 193. Magis hispidula, limbo corollæ ad lin. 2½ diametro. — The two forms are confluent. The nutlets of both at full maturity are more commonly covered with minute papillæ, but sometimes they retain their smoothness.

* * PIPTOCALYX, i. e. calyx (5-fidus, villoso-hispidus) supra basim fructum fulcrantem demum circumscissus et secedens: antheræ mucronulatæ: fructus *Eutypicarum*, nuculis ovato-acuminatis lævibus vel puncticulatis angulis lateralibus acutis sulco ventrali tenui basi divaricato-furcato tota fere longitudine gynobasi subulatæ adfixis: herba depresso-ramosissima, condensata; foliis brevibus linearibus; spicis etiam fructiferis brevibus glomeratis crebre folioso-bracteatis; corollis parvis. — *Piptocalyx*, Torr.

K. CIRCUMSCISSA. *Lithospermum circumscissum*, Hook. & Arn. Bot. Beech. 370. *Piptocalyx circumscissus*, Torr. in Wilkes Exped. xvii. 414, t. 12, B. *Eritrichium circumscissum*, Gray, Proc. Am. Acad. x. 58, Bot. Calif. i. 572, Syn. Fl. ii. 193. — Extends through the arid districts from Wyoming to Washington Territory, and south to Arizona.

§ 4. PTERYGIUM. Nuculæ *Eukrynitzkiæ* vel *Pseudokrynitzkiæ*, sed ala scariosa cinctæ, sive una exalata, gynobasi subulatæ usque ad apicem adfixæ, dorso granulato-scabræ vel muriculatæ: herbæ annuæ vel biennes, erectæ; corollæ tubo calyce haud longiore; spicis ebracteatis.

* Ala nucularum crenulata vel dentata nunc laciniata, lata, circumscriptione ovato-rotunda; vel nucula una quandoque exalata marginibus aut rotundatis aut acutiusculis: sepala ovato-lanceolata obtusiuscula.

K. PTEROCARYA. *Eritrichium pterocaryum*, Torr. in Wilkes Exped. xvii. 415, t. 13, B; Watson, Bot. King Exped. 245; Gray, Syn. Fl. ii. 195, cum var. PECTINATUM, forma ala nucularum pectinato-laciniata.

* * Ala integerrima, nucula haud latior, circumscriptione ovata: herbæ proceriores, rudes, aspero-hispidæ.

K. HOLOPTERA. *Eritrichium holopterum*, Gray, Proc. Am. Acad. xii. 81, & Syn. Fl. ii. 196. Pedalis et ultrapedalis, paniculato-ramosa, parviflora; foliis parum sesquipollicaribus linearibus. — Collected only by *Dr. Palmer*, in 1876, near Ehrenberg in Arizona, without mature fruit. A plant coll. by Dr. Palmer in 1877, at St. George, S. Utah, is in appearance between this and *K. oxygona*, with calyx silky-villous and apparently not bristly, the quite immature nutlets ovate-acute and narrowly winged.

K. SETOSISSIMA. *Eritrichium setosissimum*, Gray, l. c. Procera, bipedalis e radice bienni vel forte perenni, setis longis gracilibus hispidissima, sed foliis radicalibus (lanceolato-spathulatis cum petiolo nunc semipedalibus) pube molli canescentibus, setis fere nullis. Folia caulina lanceolata ad linearia, poll. 2–4 longa. Inflorescentia primum thyrsoideo-spicata, demum in spicis plurimis rigidis poll. 3–4 longis strictis racemoso-dispositis evoluta. Corolla limbo lin. 3 lato. Calyx fructifer lin. 4 longus, sepalis lanceolato-oblongis. Nuculæ homomorphæ, cum ala (utrinque ultra semilineam lata) ovales, lenticulares, sulco aperto insertæ. — Collected in Southern Utah and Northern Arizona, by *Ward*, *Palmer*, and *Rusby*. A remarkable and very coarse species, with much the habit of *K. glomerata*.

§ 5. PSEUDOKRYNITZKIA. Nuculæ triquetræ vel trigonæ angulis lateralibus acutatis, gynobasi plerumque subulatæ adfixæ: herbæ biennes vel perennes, paucæ annuæ; corolla fornicibus faucialibus prominulis vel exsertis et annulo 10-squamellato vel glanduloso supra basim tubi sæpius instructæ. — *Eritrichium*, § *Krynitzkia*, subsect. *Pseudo-Myosotis*, Gray, l. c., excl. spec. nuculis alatis.

* *Intermediæ,* ramosæ, parvifloræ, foliis parvis linearibus, *Eukrynitzkiis* nimis affines.

+ Annua, cymis pedunculatis sæpius bi-tri-radiatis, spicis confertifloris brevibus ebracteatis.

K. OXYGONA. *Eritrichium oxygonum,* Gray, Proc. Am. Acad. xix. 89. Facie et calyce *K. pterocaryæ* sat similis, nuculis nisi acutangulis *Typicarum.* Nuculæ paullo ultra lineam longæ, dorso parce minuteque muriculatæ, nunc fere læves nitidulæ, circumscriptione angusto-deltoideæ, sensim acutæ, angulis lateralibus acutatis, ventrali obtuso, sulco angusto basi furcato clauso tota longitudine gynobasi gracili adfixæ. Corolla limbo lin. 2 lato. — Collected by *Mr. Pringle* on the borders of the Mohave Desert in 1882, and again by *Mrs. Layne-Curran* in 1884.

+ + Basi demum lignescente perennans, paniculato-ramosissima, floribus parvis sparsis sæpe foliis fulcratis.

K. RAMOSISSIMA. *Eritrichium racemosum,* Watson in herb. Gray, Proc. Am. Acad. xvii. 226. Folia parva, cum calycibus angustis setis rigidis asperata. Nucula plerumque solitaria, tenuis, oblongo-lanceolata, scabrella, nitida. — This proves to be a rather widely spread species on the southern borders of California. It was described from a specimen collected by the Brothers *Parish* in San Bernardino Co.; has now been found in the Mohave Desert by *Mrs. Layne-Curran,* and at Point Loma and the Cantilas range on the borders of Lower California by *Mr. Orcutt;* also on Santa Catalina Island by *W. S. Lyon.* Moreover, it may now be identified with incomplete specimens collected on Cedros Island by the late *Dr. Veatch,* and on Guadalupe Island by *Dr. Palmer;* the latter wrongly referred to *Eritrichium angustifolium.* The specific name which it bore under *Eritrichium* I have replaced by a much fitter one. It was not very appropriate for the described specimen, and is still less so for those which have quite sessile or scattered flowers.

* * *Glomeratæ,* sat robustæ, e radice valida perenni vel bienni; foliis plerumque latiusculis; floribus thyrsoideo-congestis mediocribus (corolla limbo lin. 3–4 lato) hinc inde bracteatis. (Flores in nonnullis heterogono-dimorphi: stylus crassiusculus.)

The final species of this division are too widely different from true *Krynitzkia.* It might be more satisfactory to found a genus for all the following, along with *K. setosissima* (referred elsewhere on account of its decidedly winged nutlets); but the various intermediate forms forbid the taking of that course. Some tendency to heterogone dimor-

phism in the whole group is to be suspected, at least in the length of the style. For the last two species this is manifest, but sometimes low stamens are accompanied by a still lower style.*

+– Fructus (e nuculis 4 acutangulis dorso rotundatis arcte conniventibus) depresso-globosus: perennes, multicaules.

K. Jamesii. *Myosotis suffruticosa*, Torr. in Ann. Lyc. N. Y. ii. 225. *Eritrichium Jamesii* & *E. multicaule*, Torr. Bot. Mex. Bound. 140, & Marcy Rep. 294. Canescens pube adpressa molli, denique pl. m. hirsuta vel molliter hispida; caulibus brevibus decumbentibus nunc demum erectis subpedalibus; foliis obtusis oblanceolatis ad fere lineares; glomerulis demum in spicas evolutis; sepalis lanceolatis; corolla subrotata, tubo calycem haud superante lobis parum longiore, fornicibus exsertis oblongis; antheris oblongis fauci insertis; nuculis lævissimis, singulis ¼ globi depressi. — Sometimes decidedly hispid in age, sometimes canescent only with a soft and close pubescence. In the latter form it extends westward into San Bernardino Co., California, coll. *Parish.*

K. Palmeri. *Eritrichium fulvocanescens*, Watson, Proc. Am. Acad. xviii. 121, non Gray. Humilis; foliis angusto-linearibus pube strigoso-hirsuta canescentibus; caulibus calycibusque pilis patentibus hirsutissimis; corolla angusta, tubo sepala lineari-lanceolata vix superante lobis (parvulis) plus duplo longiore, fornicibus subglobosis; antheris fere linearibus; nuculis opacis rugosiusculis. — Coahuila, Mexico, forty miles south of Saltillo, *Dr. Palmer*, March, 1880, no. 895 of the distribution.

+– +– Fructus pl. m. pyramidatus; nuculis dorso convexiusculis vel planis.

++ *Breviforæ*, i. e. corolla tubo calycem haud superante limbo suo (diametro lin. 2–3½ lato) breviore, fornicibus faucialibus semiglobosis paullo exsertis: antheræ oblongæ: sepala lanceolata: nuculæ ovatæ pl. m. obcompressæ, dorso saltem scabro vel tuberculato, angulis lateralibus marginato-acutissimis, ventre parum elevato sulco tenui basi in areolam desinente percurso.

= Setis longis patentissimis hispidissimæ, semipedales ad 2–3-pedales e radice bienni.

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* *Myosotis grandiflora*, HBK., would seem from the figure to be of this group, if it came from Mexico ("in monte Orizaba, *Sch. & Deppe*," ex DC. Prodr.), and not from the Quitensian Andes. May not the latter habitat come from a transposition of the two species of *Myosotis* in the Nov. Gen. & Spec.?

K. VIRGATA. *Eritrichium virgatum*, Porter in Hayden Geol. Rep. 1870, 479. *E. glomeratum*, Gray, Am. Jour. Sci. ser. 2, xxxiv. 225, non DC. *E. glomeratum*, var. *virgatum*, Porter & Coulter, Fl. Colorad. 102. Hispida, haud canescens; caule simplicissimo cum thyrso angustissimo stricto (sæpius ultrapedali) foliato demum 2–3-pedali; cymulis etiam fructiferis perbrevibus foliis fulcrantibus angusto-linearibus brevioribus; foliis caulinis inferioribus radicalibusque angustissime spathulatis; corollæ limbo lin. 2 lato, fornicibus latioribus quam longis; nuculis vix ultra sequilineam longis lato-ovatis obtusis sæpe nitidulis dorso parce papillosis cæterum lævibus. — This we have only from the eastern slopes of the Rocky Mountains in Colorado, and it does appear to be a distinct species. The slender leaves subtending the cymes of the virgate thyrsus are an inch or two long, all but the uppermost several times longer than the flower-clusters.

K. GLOMERATA. *Cynoglossum glomeratum*, Pursh, Fl. ii. 729. *Myosotis glomerata*, Nutt. Gen. i. 112; Hook. Fl. Bor.-Am. ii. t. 162. *Rochelia glomerata*, Torr. Ann. Lyc. N. Y. ii. 225. *Eritrichium glomeratum*, DC. Prodr. x. 131; Porter & Coulter, Fl. Colorad. 102. *E. glomeratum*, var. *hispidissimum*, Torr. Bot. Mex. Bound. 140. Valde hispida; caule (cum thyrso oblongo interrupto demum aperto et in spicis fructiferis folia multo superantibus evoluto) semipedali ad sesquipedalem; foliis plerisque spathulatis, radicalibus saltem pube minuta inter setas basi demum papillosas pl. m. canescentibus; corolla limbo 2–3½ lin. lato, fornicibus æquilongis ac latis; nuculis crassioribus 1½–2 lin. longis ovatis versus apicem obtusiusculum angustatis, dorso pl. m. corrugato. — This belongs rather to the plains along the eastern base of the Rocky Mountains, from Saskatchewan to New Mexico, but extends westward to the interior of Washington Territory, and to northern parts of Arizona. It occurs both with short and with longer style.

= = Minus hispida, nana, multicaulis e caudice perenni; foliis saltem radicalibus pube molli strigoso-sericea incanis cum setis parum rigidis breviusculis plerumque incumbentibus: thyrsus etiam fructifer spiciformis: corolla lin. 2–3 lata.

K. SERICEA. *Eritrichium glomeratum*, var. *humile*, Gray, Proc. Am. Acad. x. 61, & Fl. l. c., magna parte. Nuculæ oblongo-ovatæ, obtusæ, obcompressæ, dorso subrugoso-tuberculatæ. — Alpine and subalpine, on mountains from Colorado and Utah to Oregon and Montana, and probably in the British Possessions. There are less canescent specimens from the Saskatchewan region and also from the higher Sierra Nevada (and uncertain as to the duration of the root) which

may belong either to this species or to dwarfed forms of the foregoing. I have adopted one of the two specific names under which this species occurs in Nuttall's collections.

++ ++ *Longifloræ*, i. e. corolla tubo (lin. 4–6 longo) calycem pl. m. superante limbo suo 2–4-plo longiore, fornicibus erectis elongatis (oblongis seu lanceolatis): antheræ sublineares: sepala mox elongato-linearia: styli elongati: nuculæ intus pl. m. carinatæ, a basi ultra medium usque gynobasi subulatæ adfixæ: herbæ perennes, erectæ, multicaules; caulibus superne cum thyrso spiciformi interrupto tantum villoso-hispidis; foliis præsertim radicalibus pube adpressa pl. m. incanis. Flores heterogono-dimorphi.

K. FULVOCANESCENS. *Eritrichium fulvocanescens*, Gray, Syn. Fl. ii. 197. *E. glomeratum*, pro parte, and var.? *fulvocanescens*, Watson, Bot. King Exped. 243. Spithamæa ad semipedalem, cæspitosa; foliis spathulatis nunc fere linearibus; corollæ tubo lin. 4 longo; nuculis ovatis acutiusculis opacis dorso pl. m. papillosis vel tuberculato-rugosis. — Mountains of New Mexico and adjacent borders of Texas to those of Nevada, Wyoming, &c.

K. LEUCOPHÆA. *Myosotis leucophæa*, Dougl. in Lehm. Pugill. & Hook. Fl. Bor.-Am. ii. 82, t. 163. *Eritrichium* (*Pseudo-Myosotis*) *leucophæum*, A. DC. Prodr. x. 129. Pedalis et ultra; foliis lanceolato-spathulatis nunc fere linearibus; corollæ tubo lin. 5–6 longo intus parum annulato; nuculis triquetris circumscriptione ovatis lævissimis nitidis. — Dry interior region, from Brit. Columbia to S. Utah and S. E. California. Probably the corollas are never yellow. The only indication of it is on a ticket of specimens gathered by Prof. Brewer near Lake Mono, about which there may be a mistake. The older corollas of it appear to have turned brownish, as they are said to do in the preceding species.*

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* KRYNITZKIA PHACELIOIDES, Fisch. & Meyer, is cited by Philippi Cat. Pl. Chil. 211, as a synonym of *Eritrichium phacelioides*, Clos in Gay, Fl. Chil. iv. 468, t. 52 bis. By the figure the plant seems to have an annual root and marginless nutlets; so that it is probably a *Eukrynitzkia*, but with the habit of

K. ALYSSOIDES, *E.? alyssoides*, DC. Prodr. x. 131, which would seem to include *E. gnaphalioides*, A. DC. l. c., a suffrutescent perennial, perhaps also *E. Gilliesii*, Phil., at least Reed's plant so named, and to be referred to *Pseudokrynitzkia*.

K. CLANDESTINA (*Eritrichium*, A. DC.) has already been referred to (p. 274), and it may have some earlier and better specific name. This may also be the case with *E. cryptanthum*, A. DC.

K. LINEARIS, *Myosotis linearis*, Colla, Act. Taur. xxxviii. 126, t. 42 (*Eritrichium*, DC.), an annual, has acute-edged nutlets which may refer it to the neighborhood of *K. oxygona*.

These are Chilian species, and there are many more in the books.

PLAGIOBOTHRYS, Fisch. & Meyer, nunc maxime ampliatus.*

Calyx, corolla, stamina, etc. *Krynitzkiæ.* Nuculæ lato-ovatæ vel subtrigonæ, sæpius incurvæ, crustaceæ vel coriaceæ, dorso convexo rugosæ vel asperatæ, rarissime læves, aut erecto-incumbentes, aut 2 vel 3 abortientibus succumbenti-horizontales, intus versus apicem carinatæ, versus (nunc infra raro supra) medium per pseudo-carunculam (perforatam vel solidam) gynobasi latæ adfixæ, dum secedentes foveas vel areolas depressas totidem in gynobasi nudantes. — Herbæ annuæ, Occidentali-Americanæ, humiles, sæpius diffusæ, corolla alba in plurimis parva. — *Plagiobothrys*, Fisch. & Meyer, Ind. Sem. Hort. Petrop. ii. (1835) 46, & A. DC. Prodr. x. 134; spec. typica solum. *Eritrichium* § *Plagiobothrys*, Gray, Proc. Am. Acad. x. 57, Syn. Fl. ii. 191, & Proc. Am. Acad. xvii. 226.

* Ambigui: gynobasis oblongo-pyramidata, foveis vel fossis nuculiferis elongatis ovato-oblongis seu lineari-oblongis exarata: caruncula angusta, subcarinæformis, trientem nuculæ longitudine subæquans: pubes hispido-hirsuta: flores mediocres, corollæ fere rotatæ limbo lin. 3–4 lato.

P. Kingii. *Eritrichium Kingii*, Watson, Bot. King Exped. 243, t. 23; Gray, Syn. Fl. ii. 192, maxima parte. — Eastern side of the Sierra Nevada at Truckee Pass, &c., California (first coll. by *Watson*), and adjacent borders of Nevada, *Lemmon, Mrs. Layne-Curran*, by the last two at length with mature fruit.

* * Genuini: gynobasis subglobosa vel convexa: nuculæ reticulato-rugosæ vel muriculatæ, raro lævigatæ, pseudo-caruncula aut annulari aut strumæformi (nec stipitiformi) pl. m. indurata arcte persistente instructæ, tarde secedentes, areolas depressas totidem orbiculatas in gynobasi relinquentes: flores aut pseudo-spicati nudi, aut rarius glomerati: pubes mollis (villosa vel hirsuta) necnon cum setis debilibus e basi papillosa ortis in foliis inferioribus.

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* *Plagiobothrus* was evidently intended, *βόθρος* being the word for pit or hollow, and there is no Greek word answering to *bothrys*. Although we may not correct the form of the name, we must hold to the masculine gender. Although the name, in its original application to the hollow in the face of the nutlet, is good only for the single original species, it is not far amiss for the others also, in view of the hollows left on the gynobase after the nutlets fall. These are shallow pits or depressions, or areolæ with raised borders, orbicular or nearly so except in the first species, in two or three of them with the borders so thickened or salient that the gynobase after the nutlets fall is cruciform when all four nutlets mature. More commonly only one or two nutlets ripen.

+- *Typici, Perforati:* nuculæ parum incurvæ, dorso lato convexo angustissime carinatæ, intus supra basim in pseudo-umbilicum profundum caruncula depressa annuliformi marginatum excavatæ: herbæ laxæ, graciles; spicis vel racemis cymæ uni- vel bipari demum elongatis sparsifloris fere ebracteatis; calyce alte 5-partito laxe erecto persistente. — *Plagiobothrys*, Fisch. & Meyer, & DC. Prodr. l. c.

P. RUFESCENS, Fisch. & Meyer, l. c., A. DC. l. c. *Myosotis alba*, Colla, Act. Taur. (Pl. Bert. no. 88), fide A. DC. *M. fulva*, Hook. & Arn., Bot. Beech. 38, non 369. *Eritrichium fulvum*, A. DC. Prodr. x. 132; Gray, Proc. Am. Acad. xvii. 226. — Chili, *Bertero*, *Bridges*, and others. W. California on the border of Oregon, *Howell*, and in Colusa and El Dorado Counties, *Mrs. Layne-Curran*, 1884. Also near Los Angeles, coll. *J. C. Nevin*, 1882, recently received. Only in the North American specimens which have now happily come to hand, first from Mr. Howell and then from Mrs. Layne-Curran, have I mature fruit, verifying the original character. But I am now able to verify it on a specimen of Bertero's no. 443, immature though it be. The mature nutlets in the Californian plant are from a line and a half to two lines long. Their size is not mentioned by Fischer and Meyer; by De Candolle they are said to be hardly over a line in length; probably not well grown in the cultivated plant. Neither of the authorities mentions the narrow keel on their back. Their form, "illis *Echii* subsimilis," is well given by the founders of the genus; also the "rugosa, tuberculata" by them, and the reference of this to the inner side of the nutlet by De Candolle. There is considerable variation in these respects, as well as in the texture of the pericarp, which commonly becomes cartilagineous or thin-crustaceous, the back either rugose with slender and elevated transverse wrinkles, and with or without minute papillæ in the interspaces, or with these and no rugosity, or with both obsolete. The keel and an obscure or manifest acute crest or angle on each side, between the back and inner face, are sometimes almost entire, sometimes denticulate or even muriculate, as are the sharp ventral rugæ. The "strophiole," or as I prefer to call it the (false) caruncle, is well developed in all mature fruit as a tumid ring around the orbicular cavity. It is never left behind on the gynobase, as De Candolle describes: what was taken for such may be the thickened and projecting portions of the gynobase between the insertions, which are in the hollows. These hollows when fresh are more or less umbonate, the umbo fitting into the round and ample cavity of the nutlet. The caruncular ring is complete, but the basal side is thicker than the

upper, where it connects with the narrow and salient ventral carina. There is hardly a doubt of the essential identity of the Californian with the Chilian species, although mature specimens of the latter are to be desired. And it is most probable that it is indigenous to both regions.

+ + *Scutellati:* nuculæ fere rectæ, intus supra basim caruncula ovato-deltoidea applanata scutelliformi sub centro pervio vix excavata instructæ: folia inferiora opposita.

P. PROCUMBENS. *Eritrichium procumbens*, DC. Prodr. x. 133 (*Myosotis procumbens*, Colla, l. c., ex DC.); Pl. Chili, Bertero, no. 145. A slender little plant, which, by the well-developed caruncle (the centre of which is perforate, although the nutlet is hardly at all excavated underneath it) apparently should belong to this genus, rather than to *Krynitzkia*. The nutlet is little over half a line in length.

+ + + *Imperforati:* nuculæ magis incurvæ, medio-fixæ, ad insertionem haud excavatæ, caruncula parvula imperforata strumæformi vel linguæformi instructæ: gynobasis parva, vix hemisphærica.

++ Chilensis, tenellus, "papyros violaceo colore tingens" (Ruiz & Pavon), microcarpus.

P. TINCTORIUS. *Lithospermum tinctorium*, Ruiz & Pav. Fl. Per. ii. 4, t. 114. *L. tingens*, Lehm. *Eritrichium tinctorium*, A. DC. Prodr. x. 132.

++ ++ Amer. Bor.-Occidentales.

= Nuculæ maturæ intus concavæ, basi apiceque abrupte contractis quasi cruciatim quadrilobæ, vitreo-crustaceæ, nitidulæ, dorso transversim lineato-rugosæ, nempe lineis rectis angustissimis impressis inter rugas latas a marginibus subcristatis ad carinam parum elevatam percursæ: herbæ parvulæ, erectæ; calyce alte 5-fido persistente vel sero juxta basim imperfecte circumscisso, lobis lato-lanceolatis pube primum rufescente demum fulva villosis.

P. TENELLUS. *Myosotis* (*Dasymorpha*) *tenella*, Nutt. in Hook. Kew Jour. Bot. v. 295. *Eritrichium tenellum*, Gray, Proc. Am. Acad. x. 57, & Syn. Fl. ii. 192. *E. fulvum*, Watson, etc., non A. DC. Calyx fructifer lin. 2 longus. Nuculæ lineam longæ, insigniter quadrilobæ (basi fere ut apice contracta), pl. m. muriculato-asperatæ. — Not uncommon from British Columbia east to Idaho and south to San Bernardino Co., California, chiefly in the western part of the interior region.

P. Shastensis, Greene in herb. Flores majores; calyce fructifero lin. 3 longo; nuculis sesquilineam longis lævibus vel ad margines tantum muriculatis. — California, in valley at the base of Mount Shasta, *E. L. Greene*, coll. 1876. Perhaps only a variety of the preceding, the calyx of which sometimes approaches this in size.

= = Nuculæ lato-ovatæ, haud cruciatæ,

a. Vitreo-crustaceæ, vix nitidulæ, obcompressæ, dorso vix carinato lineis angustissimis impressis inter rugas latas rectas transversim percursæ: caules mox ramosi, diffuso-procumbentes, cum foliis oblongis (superioribus flores fulcrantibus) hispidulo-hirsuti, papyros herbarii violaceo colore tingentes: calyx haud circumscissus.

P. Torreyi. *Eritrichium Torreyi*, Gray, l. c. — In the Yosemite Valley and vicinity; coll. only by *Torrey* and *Lemmon*.

b. Nuculæ opacæ, nec vitreæ, nec indurato-crustaceæ, dorso parum carinato rugis sparsis angustis prominentibus subreticulatis areolas multo majores circumscribentibus instructæ, sæpeque minutim granulatæ.

1. Calyx 5-partitus vel profunde 5-fidus, sero juxta basim circumscissus vel persistens: spicæ sæpissime simplices (i. e. cymæ uniparæ), hinc inde foliatæ, irregulares: herbæ sæpius a basi ramosæ et diffusæ; corolla limbo parvo.

P. Arizonicus, Greene in herb. *Eritrichium canescens*, var. *Arizonicum*, Gray, Proc. Am. Acad. xvii. 227. Hirsutus, subhispidus pilis patentissimis, nunquam canescens, facie præcedenti subsimilis, foliis angustioribus. Calyces fructiferi haud ultra lin. 2 longi, segmentis sæpius supra fructum conniventibus, basi demum circumscissi. Nuculæ maturæ subcrustaceæ, nunc albescentes, rugis acutissimis nunc tuberculis minimis paucis instructis. — Arizona and adjacent borders of Utah, coll. *Greene*, *Palmer*, *Lemmon*, *Pringle*, *Parish*, &c. This apparently quite distinct species has been variously distributed under the names of *Eritrichium canescens* and *E. fulvum*, which in different forms it most resembles.

P. canescens, Benth. Pl. Hartw. 326. *Eritrichium canescens*, Gray, l. c. Pilis mollioribus villoso-pubescens, subcanescens. Calyces fructiferi lin. 2–3 longi, aut laxe erecti aut patenti-aperti, persistentes, raro imperfecte circumscissi. Nuculæ rugis obtusioribus. — California, from the valley of the Sacramento to Los Angeles and San Bernardino, apparently first collected by *Hartweg*. Varies in the degree of accrescence of the calyx, which in the same plant may be either loosely open or erect, or with the lobes somewhat connivent.

2. Calyx a medio tantum 5-fidus, sesquilineam longus, pube primum rufa demum fulva seu albida sericeo-villosa; fructifer parum accrescens lobis conniventibus, mox supra basim circumscissus nuculas semi-nudans: corolla inter affines insignis, limbo rotato 5-lobo ad lin. 4 diametro: caules erecti, semi- ad bi-pedales, graciles, cum foliis viridibus parce hirsuti vel pubescentes: spicæ cymæ nudæ sæpius conjugatæ vel quasi paniculatæ, demum elongatæ et graciles, ebracteatæ.

P. NOTHOFULVUS. *Myosotis fulva*, Hook. Fl. Bor.-Am., pro parte, & Bot. Beech. 369, non Hook. & Arn. Bot. Beech. 38. *Eritrichium fulvum* (A. DC. Prodr. l. c. quoad Pl. Calif.), Gray, Proc. Am. Acad. x. 57, & Syn. Fl., excl. syn., etc. *E. nothofulvum*, Gray, Proc. Am. Acad. xvii. 227. *Bothriospermi?* sp., Benth. Pl. Hartw., l. c. no. 1873. — Common throughout California and north to Washington Territory.

* * * STIPITATI: nuculæ rectiusculæ, obliquæ, gynobasi depressæ ope pseudo-carunculam pl. m. stipitiformem induratam adfixæ; areolæ gynobasis orbiculatæ parvulæ: herbæ humiles, e radice annua ramosissimæ, mox prostratæ; calyce profunde 5-partito, fructifero persistente. *Echidiocaryæ* spec., Gray, Proc. Am. Acad. xii. 164, & Syn. Fl. ii. 199.

P. URSINUS. *Echidiocarya ursina*, Gray, Proc. Am. Acad. xix. 90. Cæspitanti-depressus, undique hispidus, foliosissimus; foliis aut spathulatis aut superioribus flores pleros sæpe glomeratos fulcrantibus oblongis; corolla calycem vix superante, limbo parvo; nuculis tenuiter parciterque rugoso-reticulatis lævibus, caruncula brevi. — S. California, in Bear Valley of the San Bernardino Mountains, *Parish Brothers*, and northern confines of Lower California, *C. R. Orcutt*. Some slight papillosities are occasionally developed on the sides of the nutlets.

P. COOPERI. *Echidiocarya Californica*, Gray, Proc. Am. Acad. xii. 164, etc. Laxe diffuso-ramosus, hispidulus vel hirsutus; ramis gracilibus sparsifoliis demum sparsifloris; foliis angustioribus; floribus plerisque ebracteatis; corollæ limbo expanso lin. 2–3 lato; nuculis magis trigonis reticulato-rugosis, rugis acutis hinc inde dentato-muriculatis, caruncula stipitiformi porrecta. — Southern California, common around San Diego and eastward, first coll. by *Cooper*, later by *Parry*, *Lemmon*, *Cleveland*, *Orcutt*, &c., and within the borders of Lower California by *Parry* and *Pringle*. The stipe-like caruncle is variable in length. The comparatively recent discovery of the preceding

species of this section has made it clear that both of them should fall into *Plagiobothrys*, a genus now shown to comprise a good number of species, and considerable diversity in the form and texture of the caruncle-like body by which the nutlets are attached to the gynobase.

* * * * ANOMALI: nuculæ rectiusculæ, nec rugosæ nec muricatæ, medio vel supra medium areolis orbiculatis gynobasis depressæ adfixæ, pseudo-caruncula præmolli minus persistente: herbæ (Sierra-Nevadenses) diffusæ, ramosissimæ, rudes, hispidæ; caulibus ad apicem usque foliatis; floribus semper glomeratis foliis (superioribus latioribus basi lata arcte sessilibus) fulcratis; calycibus 5-partitis, fructiferis apertis cum pedicellis brevissimis diu persistentibus.

The first of these species would pass unquestioned for a *Plagiobothrys* of a coarser sort, with the habit of *P. Torreyi* and *P. ursinus.* The second, of similar aspect, is more anomalous in the smooth and somewhat polished nutlets, with insertion well above the middle. The insertion in both is by a small and depressed central umbo, which fits into the very shallow round areola on the gynobase, the low margins of which are continuous with the soft-fleshy annulus or collar (so soft as to become pultaceous in hot water), which goes with the nutlet when this falls away, and forms a scale-like caruncle, of variable outline, and easily broken up. For both these species we are indebted to the same zealous and sharp-sighted botanist.

P. HISPIDUS. Semipedalis; foliis inferioribus lineari- vel angusto-spathulatis, superioribus oblongis (vix semipollicaribus, flores superantibus; nuculis turgide ovatis acutis dorso leviter obtuseque carinatis undique subpapilloso-granulatis opacis medio vel paullo supra medium insertis. — Truckee, on the eastern border of California, *Mrs. Layne-Curran*, 1884.

P. GLOMERATUS. Validior; foliis latioribus sæpius ovato-oblongis; nuculis nitidis fere lævibus ovali-ovatis minus turgidis (paullulum obcompressis) dorso convexiusculo haud carinatis intus inter medium et apicem insertis. — Western part of Nevada, between Carson and Virginia City, 1883 and 1884, *Mrs. Layne-Curran.*

ECHIDIOCARYA, reduced to the typical species, E. ARIZONICA, reverts to the original character in Proc. Am. Acad. xi. 89, and Benth. & Hook. Gen. Pl. ii. 854, *E. Californica* and *E. ursina* being now referred to a subdivision of *Plagiobothrys.*

2. *Notes on some American Species of Utricularia.*

These notes were suggested by an inspection of the colored drawings which were prepared by Major John Le Conte to illustrate his "Observations on the North American Species of the Genus Utricularia," which was published in the year 1824 in the first volume of the Annals of the Lyceum of Natural History, New York, pp. 72–79. Only rude outlines of the flowers, copied from these colored drawings, were published in this paper. After the death of Major Le Conte, the original drawings for this paper, along with those of his corresponding papers upon *Viola* and *Gratiola*, came into the possession of Mr. I. C. Martindale, in whose careful hands these interesting data are likely to be preserved, as they ought to be. Mr. Martindale obligingly lent them to me at a time when I was led to believe that Le Conte's *Utricularia personata* had been wrongly combined with the *U. cornuta* of Michaux.

Major Le Conte, in his memoir upon the genus, insisted that he had never seen *Utricularia cornuta* of Michaux; but his *U. personata* is said to inhabit bogs from New England to Florida, a district over which *U. cornuta* abounds, extending quite to the northern parts of Canada. It seemed certain, therefore, that he had unwittingly included *U. cornuta* in his *U. personata*, although the characters of flowers racemed, and lower lip of corolla small, showed that he had in view a Southern form to which these particulars apply. So we had admitted only one species of this peculiar group, allowing it to be quite variable; and Benjamin (in Linnæa, xx. 305, and in Mart. Fl. Bras. x. 240) did the same, referring to *U. cornuta* not only *U. personata*, but *U. juncea* of Vahl, a native of Guiana. But there is a small flowered racemose form in the Southern Atlantic States which one cannot without much forcing combine with the large- and few-flowered *U. cornuta.* And now Le Conte's original drawings for *U. personata* are found to represent the small-flowered form in question. His drawing is of a plant bearing seven racemosely scattered flowers, with corolla not over four lines long, and the spur filiform. Although we have no specimens from Brazil or Guiana, I judge that this form does extend to these countries, and that it is the *U. juncea* of Vahl, a name to be retained. From C. Wright's Cuban collection it appears that both this and the true *U. cornuta* are in Cuba. One can hardly draw up a clear diagnosis; but the following may serve.

U. CORNUTA, Michx. Stem 1–5-flowered, the flowers approximate at summit: lips of the corolla half-inch long; lower with the two sides

fully as broad as the large palate; spur subulate, as long as the lower lip, porrect or descending. — Northern Canada and Lake Superior to Texas; also Tropical American.

U. JUNCEA, Vahl. Stem racemosely or rather spicately 4–10-flowered, the lower flowers more or less distant: lips of the corolla 3 or 4 lines long, lower in large part consisting of the high-arched palate; spur slender-subulate, at length deflexed. — *U. personata*, Le Conte in Ell. Sk. i. 23, & Ann. Lyc. N. Y. i. 77, 78. — N. Carolina in the low country, through to Texas; also Cuba to Brazil. In both species the obovate upper lip of the corolla may be either emarginate or quite entire, and the lower either abruptly short-pointed or truncate-emarginate.

I proceed to make some notes upon the other drawings which were to illustrate Le Conte's monograph.

"U. CERATOPHYLLA." A full and good figure of *U. inflata*, Walt.

"U. MACRORHIZA." In the figure the spur of the corolla equals the lower lip in length, is contracted between the middle and the base, the apical portion narrow and moderately curved upward, and the apex is emarginate. The outline in the monograph is a correct copy of the outlines of one of the two flowers represented in the drawing. Le Conte's description of it, "conic at the base, linear at the tip," appears to have been made from the figure. If this well corresponded with the American plant, one would not hesitate to agree with him that his *U. macrorhiza* is quite distinct from *U. vulgaris*, not adopting, however, his strong assertion, "that no stretch of the imagination can find any resemblance between them further than what is seen running through the whole genus." Of course he was wrong in supposing that "the *U. vulgaris* has not the fruit cernuous," as much so as has the American plant. As to the spur in our American plant, the emargination is certainly uncommon; the tapering is gradual from base to tip; and it is only in the length and consequent slenderness that the American form obviously differs from the European. No known American specimens have the short and truly conical dependent spur of the old figures, such as those of Schkuhr's Handbuch and the original and later editions of the English Botany; but those of Cosson's Atlas and Reichenbach's Icones Floræ Germanicæ answer well for our plant, except that the spur in ours is commonly (but not always) longer, yet seldom more so, or more curved, than in fig. 7 of Reichenbach's tab. 1823 (202). The proportions of the palate to the lamina of the lower lip in *U. vulgaris*, var. *Americana*, as well in Le Conte's figure as in our specimens, are rather those of *U. neglecta*, Lehm., or *U. major*,

Schmidel and Reichenbach. If that be taken for a variety of *U. vulgaris,* all the more should the *U. macrorhiza* of Le Conte, an extreme form of the common N. American species. I have never seen a spur of the latter so long in proportion and so abruptly contracted as in Le Conte's figure.

"U. STRIATA." The drawing bears the name of "*U. biflora,* Vahl," which in the monograph this is thought probably to be. A diagnosis written in pencil under the figure seems to identify it with *U. striata,* and begins with "caule bi–trifloro." The published character in the monograph says "5–6-flowered," which is certainly wrong. The figure has only two flowers, on a stem barely a span high, which is smaller than usual. It represents the species which has been always taken for *U. striata,* and which is referred in the Synoptical Flora to *U. fibrosa,* Walt. But the outline of the flower in the monograph (fig. 4) is not taken from the drawing, nor from any figure in the collection, and the spur in the two does not quite correspond. So that the identification is rather doubtful.

"U. GIBBA." From the drawing (6-flowered) and the description (4–7-flowered), this should be *U. minor,* L., except that the proportion of the parts of the corolla is that of *U. gibba.*

"U. FORNICATA." The drawing which I suppose to represent this species bears no name. It is obviously *U. gibba,* L.

"U. LONGIROSTRIS" obviously represents the species which I take for *U. biflora,* Lam. This name should therefore in the Flora be made a synonym of that species, and be excluded from *U. fibrosa.*

"U. INTEGRA," from the drawing (if rightly identified, for it is without name), as well as from the description, I judge to be specifically the same as the last preceding, the spur rather stouter. Only the tip of it is represented in fig. 8 of the monograph.

"U. PURPUREA." It is the large-flowered form that is represented, probably from New Jersey.

"U. PERSONATA." *Vide supra.*

"U. SETACEA." The *U. subulata,* L., of which it is said that "nothing worthy the name of a description exists." This is true as to Gronovius and Linnæus. Both were evidently puzzled by Clayton's "Pyrola floribus albis spicatis," etc., which somehow or other got affixed to this *Utricularia* in the manuscript.

U. CORNUTA, Michx., is barely enumerated in the monograph, but not figured, having been confounded with *U. personata. Vide supra.*

Two other tropical species claim a place in our flora, having been detected in Florida.

U. LONGECILIATA, A. DC., is already in the published lists. It is a well-marked little species of Brazil, Guiana, and Cuba; it was collected by the late Dr. Garber in Florida, at Tampa and at Manatee, in 1877, but it did not reach me in time to be included in the first part of the Synoptical Flora.

U. SIMPLEX, C. Wright in Wright & Sauvalle, Flora Cubana, a small and spicately several-flowered species (which may have some earlier name), was collected by Miss Mary C. Reynolds at St. Augustine, Florida, in the autumn of 1879.

U. SUBULATA, L., var. CLEISTOGAMA, seems to be not uncommon. The late Dr. Garber collected it in Florida, and Mrs. Owen sends it from the island of Nantucket.

U. PURPUREA, Walt. In the Synoptical Flora it was questioned whether the plant there described is the species of Walter, on account of his "floribus parvis," those of the plant in view being "over half-inch broad," and the lips being spreading. My character was from Northern specimens. I had some from Georgia and S. Carolina, of a more slender plant with smaller flowers, which were thought to be imperfectly developed. But Mr. Curtiss has since sent fine specimens, answering to Walter's character, and to that of Chapman, who gives the breadth of the flower at four lines. At the same time he sends from Eastern Florida specimens exactly like the robust and larger-flowered plant of the Northern States. Wright's Cuban specimens seem to be intermediate. It remains to be determined whether the *U. saccata* of Elliott (the name of which Le Conte ignores) is the large or the small-flowered species, and whether fresh flowers of the two would furnish distinctive characters. If so, names for the two species are ready. The plant mentioned in Ell. Sk. i. 24, as probably the *U. purpurea* of Walter, must rather have been a purplish-flowered *U. subulata*. Walter evidently had a floating species in view.

3. *New Genera of Arizona, California, and their Mexican Borders, and two additional Species of Asclepiadaceæ.*

The character of the first of these genera has already been printed in the Bulletin of the California Academy of Sciences, 1884, no. 1, p. 4.

VEATCHIA, Nov. Gen. *Anacardiacearum.*

Flores dioici; ♂ ignoti. ♀ Sepala 5, brevia, deltoideo-ovata, æstivatione subvalvata, immutata. Petala 5, ovato-oblonga, æstivatione

imbricata, costa extus prominente carinata, evenia, scarioso-accrescentia, persistentia. Stamina sterilia 10, minuta, sed antherifera, sinubus disci pateræformis 10-crenulati inserta. Ovarium ovatum, subobliquum: styli 3, subulati: stigmata capitata. Ovulum a funiculo elongato supra-basilari adscendente pendulum. Fructus immaturus utriculatus (corollam marcescentem haud superans), compressus, apice hinc exciso obliquus, pericarpio prorsus membranaceo haud alato. — Frutex pinnatifolius; floribus parvis paniculatis rubellis vel (ut dicitur) læte rubris.

VEATCHIA CEDROSENSIS. — Foliis canescenti-puberulis; foliolis 3–5-jugis cum impari ovatis ovalibusque parvis (lin. 1–3 longis) integerrimis vel obsolete paucidentatis, terminali quandoque trilobo; pedicellis et ovario villosulis; petalis calyce plus duplo longioribus demum $\frac{1}{4}$-pollicaribus. — *Rhus Veatchiana,* Kellogg, in Proc. Cal. Acad. ii. 24. — Cedros Island, Lower California, *Dr. J. A. Veatch.*

In his recent monograph, Prof. Engler suggests that this plant, judging from the figure, may be a *Bursera.* But no figure is given or referred to in our copy of the Proceedings of the California Academy, in which Dr. Kellogg, although describing it as a *Rhus,* thought it was closely allied to *Sapindaceæ.** An original specimen, kindly communicated by the California Academy, enables me to bring to view its real characters, and to found on it a new genus; the fruit of which (though quite immature) cannot be either drupaceous or samaroid, but is obviously utricular.

We may dedicate this genus to the memory of its discoverer, the first and [except Lieut. L. Belding] perhaps still the only botanical explorer of Cedros Island. The genus *Veitchia* among the Palms need not stand in the way of this merited honor, for the Latinized names differ in pronunciation as well as in orthography.

LYONOTHAMNUS, Nov. Gen. *Rosacearum?*

Flores hermaphroditi. Calyx 1–3-bracteolatus: tubus hemisphæricus: lobi 5, æstivatione imbricati. Discus tubum calycis vestiens, lanatus, margine vix incrassato 10-crenulato. Petala 5, orbiculata,

* Since this account was printed in the California Bulletin, I have received a copy of the plate referred to, a colored lithograph from Dr. Kellogg's drawings, representing a flowering branch of the natural size, and a probably in part ideal figure of what seems to be a low tree or tree-like shrub, with a thick and short trunk and widely spreading branches of extraordinary thickness, the branchlets covered with pale red or pink flowers.

prorsus sessilia, æstivatione imbricata. Stamina 15, margini disci cum petalis inserta (ante petala gemina, ante sepala solitaria): filamenta simplicia filiformia. Carpella 2, libera et discreta, in fundo calycis arcte sessilia: ovaria ovata, intus complanata, processibus setiformibus brevibus undique instructa, stylo crasso terminata: stigma subcapitatum. Ovula 4, pendula, oblonga. Folliculi ——— ?—Arbuscula insignis; foliis oppositis lanceolatis petiolatis neriiformibus subintegerrimis; stipulis nullis; gemmis annotinis perulatis; floribus in cyma terminali corymbiformi amplissima numerosissimis; petalis albis.

LYONOTHAMNUS FLORIBUNDUS. — Island of Santa Catalina, California, on a high and exposed rocky ridge of the northwest part of the island: a single group found, of arborescent shrubs, 12 to 14 feet in height, collected by *William S. Lyon*, July, 1884.

This striking shrub is one of the fruits of Mr. Lyon's exploration of Santa Catalina Island, the first thorough one which has yet been made. As a well-earned acknowledgment of the discoverer's enterprise in botanical exploration, I propose that the genus shall bear his name. Preoccupation stands in the way of the usual form; but the name chosen, which denotes that this is Mr. Lyon's shrub, will not be thought amiss. To the characters above given it may be well to add, that the young foliage, branches of the cyme, and the calyxes are covered with a fine and soft pubescence, which is deciduous from the leaves, at least from their upper face; that the latter are 4 or 5 inches long, mostly rounded at the base, which is occasionally sinuate-lobulate: they are coriaceous, transversely many-veined in the manner of *Nerium*, but the veins more prominent beneath. The flowers (with petals only a line or two long, little exceeding the calyx-lobes), though individually small, are so numerous and crowded in the very broad and ample compound cymes (of sometimes a foot in diameter) that they make a fine show.

Whether this genus is Rosaceous or Saxifragaceous cannot be fairly determined until the fruit is known. I am disposed to refer it to the former, and to the neighborhood of *Vauquelinia* and *Lindleya*, notwithstanding the opposite and exstipulate leaves. If Saxifragaceous, it may be associated with *Jamesia.*

PRINGLEOPHYTUM, Nov. Gen. *Acanthac.-Justiciearum.*

Calyx minute 2-bracteolatus, 5-partitus, segmentis æqualibus oblongo-linearibus rigidulis 3-nervatis. Corolla subdeclinata: tubus cum fauce brevi vix ampliori cylindraceus, limbo paullo longior: limbus

bipartitus; labiis patentibus, postico bipartito lobis oblongis, antico trifido majore, lobis obovatis, intermedio emarginato. Stamina 4, fauci inserta, subinclusa: filamenta brevia, antica villosissima: antheræ uniloculares, ovato-oblongæ, anticæ secus connectivum villosæ, posticæ cum filamento fere nudæ. Stylus filiformis: stigma emarginatum. Ovarii loculi biovulati. Capsula oblonga, subteres, nec stipitata nec basi attenuata, disperma. Semina ovalia, subturgida, furfuracea. — Suffrutex glaucescens; ramis gracilibus; foliis lanceolatis integerrimis, floralibus ad bracteas calycibus breviores reductis; floribus parvulis graciliter interrupte spicatis; corolla ut videtur purpurascente.

Pringleophytum lanceolatum. — Northwestern borders of Mexico, in Sonora; on rocky hills fifty miles below Altar, and thirty miles from the Gulf of California, coll. *C. G. Pringle*, 1884. Genus allied to *Holographis* of Nees, which, although unknown to the authors of the new Genera Plantarum, has been identified by Hemsley with no. 1211 of Coulter's Mexican collection, from Zimapan. Nees does not describe the upper lip of the corolla: in Coulter's specimen this is erect and entire. In the present genus it is 2-parted, as much disposed to be patent as the lower lip; the throat is not ampliate, only two of the anthers are pubescent, and the filaments of these are woolly-bearded.

This genus is dedicated to the discoverer, Mr. C. G. Pringle of Vermont, one of the most zealous and enterprising of our botanists and the best of collectors, whose explorations in former years have brought many new and interesting plants to light. The present genus and the following new genera are among the fruits of very arduous and hazardous excursions made during this year from Arizona into the northwestern borders of Sonora, where no botanist had hitherto penetrated. The lengthened name here chosen is necessary on account of the *Pringlea* in *Cruciferæ*, which commemorates the celebrated Sir John Pringle of a century ago.

PHAULOTHAMNUS, Nov. Gen. *Phytolaccacearum*.

Flores dioici. Calyx 4-partitus, segmentis herbaceis rotundatis valde imbricatis. Discus nullus. *Masc.* Stamina 12, circa rudimentum (nunc evanidum) ovarii inserta: filamenta distincta, tenuia, antheris lineari-oblongis basifixis breviora. *Fœm.* Ovarium ovoideum, prorsus liberum, uniloculare, uniovulatum. Stigmata 2, filiformia. Ovulum in funiculo basilare erectum, amphitropum. Fructus tenuicoriaceus, indehiscens, calyce erecto semi-inclusus. Semen pericarpium

implens, reniforme; testa crustacea nitida. Arillus nullus. Embryo fere annularis, albumen parcum cingens: cotyledones angusto-lineares, planæ, vix inæquales, radicula gracili longiores. — Frutex boreali-Mexicanus, orgyalis, glaber; ramulis divaricatis spinescentibus; foliis alternis nunc fasciculatim confertis spathulatis parvis integerrimis; floribus parvis racemulosis brevipedicellatis parvi-bracteatis.

PHAULOTHAMNUS SPINESCENS. — N. W. Sonora, Mexico, about thirty miles south of the U. S. boundary, and on the Rio Altar, nearer the line, *C. G. Pringle*, August, 1884. The name (φαῦλος, θάμνος) indicates that this is an uncomely shrub, ill to handle. But it is an interesting addition to the order *Phytolaccaceæ*.

HIMANTOSTEMMA, Nov. Gen. *Asclepiadacearum.*

Calyx 5-partitus, sinubus squamella minima instructis. Corolla alte 5-partita, mox reflexa, intus saltem basi processibus plurimis corollinis spathulatis insigniter ornatis; lobis lato-lanceolatis æstivatione dextrorsum leviter obtegentibus. Corona staminea apici columnæ brevis filamentorum affixa, simplex margine membranacea, ligulas 10 prælongas angusto-lineares stipitatas per paria antheris alternantes, et 5 breves subulatas antheris oppositas eaque haud superantes uniseriatim gerens. Antheræ breves, sinubus stigmatis parum dilatati et angulati vertice depressi appositæ, inappendiculatæ, loculis apice hiantibus. Pollinia ovalia, apice pellucido caudicula brevissima appensa, introrsum subpendula. Folliculi fusiformes, echinati. — Herba boreali-Mexicana, vix volubilis, puberula; foliis oppositis sagittato-cordatis; pedunculis axillaribus umbellato-bifloris; corolla extus viridula intus brunneo-purpureis; ligulis coronæ viridulis.

HIMANTOSTEMMA PRINGLEI. — Along water-courses among the rocky hills of N. W. Sonora, Mexico, south of Altar, and about thirty miles from the Gulf, *C. G. Pringle*, August, 1884. — Stems diffuse from a perennial root, a foot or two long, probably feebly voluble, slender. Leaves less than an inch long, and the petiole of equal length. Peduncle short, 3–4-bracteate at the summit, bearing usually two flowers on elongated pedicels. Calyx-lobes linear-lanceolate. Corolla-lobes 4 lines long, thickish, veinless; the upper face sometimes nearly naked, usually beset with some sparse trichomes, like those of the throat, but smaller; the throat or base of the corolla conspicuously adorned with these singular corolline processes, which are sometimes very numerous, sometimes fewer, but in no obvious order, of purplish hue, fully a line in length, apparently flat, spatulate in form, and

stipitate. The long divisions of the corona are fully 2 lines in length, $\frac{1}{8}$ of a line wide, erect, in the just opening blossom nearly equalling the corolla; they are accordingly very conspicuous: the five subulate processes opposite the anthers are inconspicuous and are somewhat incurved. The stigmatic disk is smaller in proportion than in most *Gonolobeæ*, and does not at all cover the anthers: these are wholly destitute of scarious apical appendages, and the pollinia are obviously pendulous and disposed to be vertical. Still the affinity of this plant seems manifestly to be with *Gonolobus* and *Polystemma*. It cannot well be referred to the latter, although it may be near it. The generic name (ἱμάντος, στέμμα) refers to the strap-shaped lobes of the corona.

ROTHROCKIA, Nov. Gen. *Asclepiadacearum*.

Calyx 5-partitus, intus squamellis minimis 3–4 instructus. Corolla rotata, profunde 5-fida, lobis oblongis anguste dextrorsum convolutis. Corona simplex, imæ basi corollæ et tubo stamineo inserta, 5-partita, lobis antheris oppositis crassis subcuneatis vix cucullatis. Antheræ breves: pollinia ovalia, sub apice caudiculæ brevi adfixa, pendula. Stigma vertice in columnam apice tricristatam producto. Folliculi crassiusculi, acuminati, læves. Semina comosa. — Herba volubilis, pubescens, basi suffrutescens; foliis oppositis cordatis acuminatis longe petiolatis, petiolis ramisque patenti-hirsutis; cymis axillaribus laxis bracteolatis demum racemiformibus; corolla albida.

ROTHROCKIA CORDIFOLIA. — Southern Arizona (Catalina Mountains, &c.), where it seems to have been first collected by *Lemmon*, in April, 1881, in fruit only, and the specimens taken for *Roullinia unifaria*, perhaps distributed under that name: in 1884 collected by *Pringle*, both in flower and in fruit, in Northwestern Sonora (along with *Himantostemma* and *Pringleophytum*) in a range of rocky hills southwest of Altar.

The genus is dedicated to my friend and former pupil, Dr. J. Trimble Rothrock, Professor of Botany in the University of Pennsylvania, at Philadelphia, a keen botanist and zealous teacher, an explorer both in Alaska and in Arizona, author of a Sketch of the Flora of Alaska, and of the Botany of Wheeler's Report upon the U. S. Surveys of Arizona and Southern California, and whose name it is well to commemorate in an Arizono-Mexican genus. The plant seems most like *Enslenia*, *Roullinia*, or the *Endotropis* section of *Cynanchum*. Its main peculiarity is in the apical process of the stigma, a short and thick body with dilated base, somewhat longer than the whole column, its apex

dilated into two divaricate lobes or crests, which are muriculate-papillose, and between these a smaller and emarginate central crest is interposed.

LACHNOSTOMA ARIZONICUM. Pilis brevibus pubescens; caulibus gracilibus libenter volubilibus; foliis membranaceis cordato-sagittatis; pedunculis gracilibus 2–7-floris; corollæ albæ extus glabræ tubo sepala subæquante lobis ovato-oblongis parce viridi-reticulatis vix breviore, fauce retrorsum villosa; corona simplici nuda crateriformi præter marginem liberum crassiusculum 10-crenatum tubo corollæ adnata (eo vestiente); columna filamentorum longiuscula; folliculis ovoideo-lanceolatis lævibus glabris. — Southern Arizona; in the Santa Catalina Mountains, *Lemmon* (no. 3036, coll. 1883), distributed as *Gonolobus reticulatus;* and in the same district, coll. *Pringle*, 1884. — The main distinctions between *Lachnostoma* and *Gonolobus*, namely, the short-salverform or at least tubular-based corolla of the former, with corona adnate to the tube, were indicated in Proc. Am. Acad. xii. 74, when the only true species then known was the original *L. tigrinum*, HBK. Since then, in Bot. Biol. Centr.-Amer. ii. 335, Hemsley has added a second species, from Guatemala; and I consider that we have a third in the present plant. The principal structural difference is that the corona is not produced beyond the adnate portion into five two-lobed squamæ; but these are represented by the ten crenulations or short lobes of its free border. These are glabrous: the villosity belongs wholly to the throat of the corolla. The filaments are somewhat longer than in *L. tigrinum*, and, though monadelphous, are disposed to separate in withering flowers.

ACERATES BIFIDA, Rusby in litt. *A. viridifloræ* sat similis; foliis omnibus oppositis puberulo-tomentosis lato-lanceolatis basi attenuatis; floribus paullo minoribus longius pedicellatis; cucullis pallidioribus antheris parum brevioribus *bipartitis*, segmentis lanceolatis. — Arizona, coll. *Dr. H. H. Rusby*, 1883, probably in Yavapai Co., in a single specimen. — Botanists collecting in Arizona should find again this remarkable species, so peculiar for its divided hoods. It has probably escaped attention on account of its near general resemblance to the polymorphous and widely diffused *A. viridiflora*. It might be referred to the section of the genus which contains that species, or a new section may be made for it, indicating the peculiarity of the two-parted hoods, of which there is no trace in any other species of *Acerates*. The discoverer had not unnaturally taken the plant for a *Gomphocarpus*, but it clearly belongs to the present genus.

4. *Gamopetalæ Miscellaneæ.*

Compositæ.

BRICKELLIA NEVINII. E basi fruticosa multicaulis, tomento mollissimo subfloccoso incana; ramis gracilibus usque ad capitulas corymboso-thyrsoideas foliatis; foliis alternis parvulis, caulinis semipollicaribus ovatis repando-subdentatis brevipetiolatis, superioribus ramealibusque bracteiformibus arcte sessilibus; capitulis 30–40-floris semipollicaribus; involucro oblongo pluriseriali, bracteis obtusiusculis paucistriatis, exterioribus lanceolatis subfoliaceis parum squarrosis, intimis angustolinearibus; pappo minute scabro. — Los Angeles Co., California, near Newhall, Oct. 1884, *J. C. Nevin.* A remarkable species, white-woolly in the manner of *B. incana* and *B. Hartwegi*, in other respects allied to *B. microphylla*

APLOPAPPUS ORCUTTII. *A. squarroso* affinis, pariter fruticosus, fere glaber; ramis virgatis; foliis resinoso-punctatis mox glutinosis spathulato-lanceolatis acutatis integerrimis crasso-coriaceis; capitulis plurimis in thyrsum strictum digestis iis *A. squarrosi* minoribus et angustioribus 15–18-floris; involucri bracteis apice viridulo squarrosopatente viscoso-puberulis; floribus radii 2–4 fertilibus ligula parva discum paullo superante; fl. disci appendicibus styli lato-lanceolatis parte stigmatica plus dimidio brevioribus; acheniis (junioribus) pubescentibus. — All Saints' Bay, in the northern part of Lower California, C. R. Orcutt, Sept. 1884. An interesting species, connecting the rayless *A. squarrosus* with the radiate Pyrrhocomoid species.

ERIGERON NUDATUS. *E. Bloomeri* proximus, glaberrimus, lævis; caulibus cæspitosis brevissimis folia conferta spathulato-linearia obtusa crassiuscula fere evenia gerentibus; pedunculis scapiformibus simplicibus monocephalis ultraspithamæis; involucri biserialis bracteis æqualibus crassiusculis lanceolatis acutis prorsus viridibus aut glaberrimis aut pilosiusculis glabratisque; ligulis nullis; acheniis obovato-oblongis parce pubescentibus; pappo simplici albido. — Dry hillsides, Waldo, S. W. Oregon, *Howell*, June, 1884.

SILPHIUM BRACHIATUM, Gattinger.* Caule quadrangulo (3–5-pedali) foliato cum ramis floriferis brachiatis gracillimis subnudis teretibus glabro lævique; foliis oppositis supra hispidulo-scabridis, caulinis longiuscule petiolatis deltoideo- vel hastato-lanceolatis subdentatis, petiolo parum marginato hispido-ciliato, ramealibus dissitis

* Now described by the discoverer in Coulter's Botanical Gazette, ix. 192.

parvulis sessilibus integerrimis; capitulis longe pedunculatis parvulis; involucri bracteis ovatis; acheniis obovato-orbiculatis angusto-alatis apice parum emarginatis. — Mountains of Eastern Tennessee, near the Tunnel at Cowan, Franklin Co., on limestone, *Dr. A. Gattinger*, coll. July 14, 1867. By a singular mischance this very distinct *Silphium* was not made known to me until after the publication of the Compositæ in my Synoptical Flora. A subdivision should be provided for it, to follow that which contains *S. perfoliatum*. The cauline leaves are 6 to 10 inches long, on petioles of $1\frac{1}{2}$ to 2 inches; the small and remote leaves of the slender flowering branches are only an inch or two in length, the 1–3-flowered peduncles 3 or 4 inches long and almost filiform. Involucre little over half an inch high. Rays rather few, half an inch long. Akenes 4 lines long.

FRANSERIA FLEXUOSA. *Acantholæna, F. deltoideæ* affinior, frutescens, canescens, mox glabrescens; ramis gracilibus flexuosis; foliis deltoideo-lanceolatis vel basi breviter cuneatis brevipetiolatis attenuato-acuminatis parce spinuloso-dentatis laciniatisque rigidis transverse penniveniis e costa valida subtus reticulatis; panicula aphylla; involucris fructiferis brevi-ovoideis 2–3-floris (lin. 2–3 longis) pubescentibus aculeis paucis (7–8) validis subulatis e basi lata mox recurvis (apice recto) armatis. — Cañon Cantillas, within the borders of Lower California, *Orcutt*, 1884. The foliage is somewhat like that of *F. ambrosioides*, but with the rigidity of *F. ilicifolia*, yet the teeth or lobes of the leaves are hardly spinescent. The fruit is that of the *Acantholæna* section of the genus, its spines thicker than those of *F. deltoidea*, and beset with short pubescence.

HELIANTHUS TEPHRODES, Gray. Annuus; caule ramoso pl. m. hispidulo; foliis ovato-lanceolatis seu ovato-oblongis subintegerrimis (circ. pollicaribus) longius petiolatis utrinque ramisque pube sericeo-strigosa incanis; involucri (lin. 4–5 alti) bracteis lanceolatis subacuminatis fere æquilongis; receptaculi paleis subintegerrimis acutis plerumque glabris; acheniis lineari-oblongis vel subclavatis turgidis (parum compressis sericeo-pilosis vel inferne glabratis); pappo caduco e squamellis 2 oblongis vel linearibus pilis apicalibus achenii aut brevioribus aut longioribus. — Bot. Mex. Bound. 90. *Viguiera nivea*, Gray, Bot. Calif. i. 354, excl. syn. *V. tephrodes*, Gray, Syn. Fl. ii. 271. *Gymnolomia encelioides*, Gray, Proc. Am. Acad. xix. 4, & Syn. Fl. ii. 269. — Complete specimens, with some mature fruit, from "sand-hills in N. W. Sonora, near the Gulf," coll. Pringle, 1884, now at length fix this species under the name which I first applied to very scanty and imperfect materials, and show that what were taken for fine

setiform or dissected squamellæ between the small or minute paleæ are only hairs of the akene. And my *Gymnolomia encelioides* proves to be a more robust and less hoary form of the same species, with ampler rays, the pappus in some flowers very manifest.

HELIANTHUS OLIVERI. E grege *H. Parishii* et *Californici*, indumento molli insignis, elatus, sat ramosus, foliosus, floribundus; ramis superne villoso-hirsutis vix scabris; foliis utrinque pube mollissima canescenti-tomentosis (subtus præsertim) alternis lanceolatis acuminatis fere integerrimis juxta basim acutiusculam triplinerviis brevipetiolatis; involucri bracteis lineari-subulatis laxis albo-villosis; pappi paleis e basi lata subulatis. — Coast of California, Cienega, between Los Angeles and Santa Monica, *J. C. Oliver;* received from *J. C. Nevin*, 1884. It is said to attain a height of ten or twelve feet, and its soft and rather villous than tomentose pubescence is remarkable.

VERBESINA DISSITA. Herbacea, fere glabra et lævis; caule elato tereti prorsus aptero; foliis oppositis, caulinis (imis ignotis) internodiis valde brevioribus ovatis serratis basi angusta sessilibus tenui-membranaceis subtriplinervibus venosis; capitulis in pedunculo subpaniculatis (semipollicaribus); involucro multifloro cinereo-puberulo, bracteis pauciusculis lineari-lanceolatis acutis disco brevioribus; ligulis paucis neutris; acheniis cum alis latis obovatis fere glabris, aristis basi alæ coalitis. — Near All Saints' Bay, Lower California, Sept. 1884, *C. R. Orcutt.* — This is the only known species of the *Pterophyton* section in any part of California, except the allied *V. venosa*, Greene (in Proc. Am. Acad. xix. 13). It is of the naked-stemmed group, apparently a full yard high, and with the pairs of leaves remote.

Chænactis suffrutescens, which was founded on Lemmon's plant from the northern part of California, was in the Synoptical Flora, i.[2] 341, confounded with a related species from the southern borders of the State, and the proper habitat was unreasonably discredited. Both are suffrutescent-perennial: they may be distinguished as follows.

CHÆNACTIS SUFFRUTESCENS, Gray. Tomentoso-incana; ramis e caule decumbente lignoso erectis simplicissimis apice nudo monocephalis; foliis pinnatipartitis, lobis angusto-linearibus integerrimis; capitulo fere pollicem alto; pappi paleis 10 semper oblongo-lingulatis. — Proc. Am. Acad. xvi. 100, & Syn. Fl. l. c. pro parte. — Sandwashes of the Upper Sacramento, California, near Mount Shasta, *Lemmon* 1879.

CHÆNACTIS PARISHII. Canescens; caulibus basi suffrutescentibus parce ramosis oligocephalis; foliis pinnatipartitis, lobis linearibus

brevibus integriusculis; capitulo vix ultra semipollicem alto; pappi paleis linearibus 13–15. — *C. suffrutescens*, Gray, Syn. Fl. l. c., quoad pl. coll. Parish. — On the southern border of California, 1882, *Parish Brothers*, and near Hanson's Ranch, within Lower California, *C. R. Orcutt*, 1884.

Microseris Howellii. *Scorzonella*, post *M. sylvaticam;* caule gracili e radice fusiformi 1–3-cephalo sæpe ramoso; foliis elongatis (majoribus pedalibus) angusto-linearibus sursum attenuatis aut integerrimis aut lobulis paucis refractis; capitulis parvulis 15–20-floris; involucri bracteis acuminatis, interioribus (semipollicaribus) oblongo-lanceolatis exteriores paucas basi subovatas 2–3-plo superantibus; pappi setis 8–10 nudis (sub lente tantum denticulatis) basi in paleam lanceolatam 4–5-plo breviorem sensim dilatatis. — Waldo, S. W. Oregon, June 3, 1884, *Howell.*

Ericaceæ.

Cassiope oxycoccoides. Habitus *Loiseleuriæ* vel *Vaccinii Vitis-Idææ* depauperatæ; foliis plerisque oppositis ellipticis crasso-coriaceis (lin. 2–3 longis) aperte petiolatis, marginibus pl. m. revolutis, costa subtus prominente; pedunculo terminali brevi apice involucratim 4-bracteato trifloro; pedicellis brevissimis; floribus 5-meris; corolla sepalis oblongis subduplo longiore sub-urceolato-campanulata, ore breviter 5-lobo. — A peculiar little plant, growing among Mosses and Lichenes, along with *Diapensia*, on Behring or Bering Island, off the coast of Kamtschatka, coll. 1883 by *Dr. L. Steineger*, a single specimen only in the collection, where *Bryanthus Gmelini* was also gathered. It appears to be a congener of *Cassiope Stelleriana*, but with a narrower mouth and much shorter lobes to the corolla, and a different habit and foliage, as the comparisons in the specific character indicate. Dr. Steineger made interesting collections on these islands, so long ago explored by Steller and little visited since. A list of the plants gathered by him, with interesting notes, is published in the Bulletin of the National Museum, Washington.

SCHWEINITZIA, *a Genus of two Species.*

The discovery of a second species of a genus supposed to be monotypical is always interesting, the more so when the genus itself is peculiar. The genus *Schweinitzia* of Elliot, a member of the *Monotropeæ*, is of this kind. Some time ago I received from Miss Mary C. Reynolds, at first indirectly and then directly, specimens which differ from the original *S. odorata*, and now (December 9) I am

favored by the discoverer with a full series of freshly gathered specimens. I am convinced that two species are to be distinguished, and that they may be characterized as follows.

S. ODORATA, Ell. in Nutt. Gen. Addend., & Sk. i. 478; Gray, Chloris Bor.-Am. 15, t. 2, & Syn. Fl. ii. 49, ubi syn. Squamis caulem pl. m. imbricantibus lato-ovatis; floribus breviter spicatis parum cernuis; sepalis oblongis corollam "carneam" subæquantibus. — Maryland, near Baltimore, to North Carolina, from the middle country to the Blue Ridge.

S. REYNOLDSIÆ. Gracilior; squamis parvulis (lin 1–3 longis) haud imbricatis; spica angusta secundiflora nuda e floribus sat numerosis mox nutantibus; sepalis ovatis seu ovato-lanceolatis corolla alba (vix lin. 3 longa) dimidio brevioribus. — E. Florida, near St. Augustine and on Indian River, flowering in November and December, under scrub oaks, in dry sandy soil: collected only by *Miss Reynolds*, whose name the species is to commemorate. The plant is said at times to exhale a slight spicy fragrance.

Polemoniaceæ.

GILIA BELLA. *Dactylophyllum*, post *G. auream*, e basi ramosa; caulibus filiformibus spithamæis lævibus; foliis parcis brevissimis tripartitis cum nodo villosulis, segmentis lato-linearibus carinatis; pedunculis seu potius ramis floridis sæpe proliferis flores 2–3 inter bracteas subsessiles gerentibus; calycis lobis folia referentibus crasso-carinatis fere ad apicem hyalino-marginatis; corolla infundibulari-campanulata (lin. 5 longa), tubo calycem æquante flavo, fauce atro-purpureo maculata, lobis violaceis flabelliformibus integerrimis tubo æquilongis; filamentis basi pilosulis; ovarii loculis multiovulatis; seminibus madidis haud mucilaginosis. — At Hanson's Ranch, Lower California, near the boundary, *Orcutt*, 1884. A pretty species, abundantly floriferous.

GILIA (PHLOGANTHEA) MACOMBII, Torr. in herb. A basi vel caudice suffrutescente multicaulis, puberula; caulibus 1–2-pedalibus glomerato-thyrsifloris; foliis rigidulis in segmenta 3–6 rhachi haud latiore pinnatipartitis vel superioribus integerrimis filiformi-linearibus; corolla violacea hypocraterimorpha, tubo sursum leviter ampliato semipollicari calyce hirsutulo vel glabello 3–4-plo longiore, lobis æqualibus obovatis mucronulatis; staminibus inæqualiter insertis 2–4 (sæpius 3) e fauce breviter exsertis, filamentis rectis; ovarii loculis 3–6-ovulatis. — This is *Gilia multiflora*, Torr. Bot. Mex. Bound. 146, in part, and part of *Collomia Cavanillesiana*, Gray, Syn. Fl. ii. 136, being Wright's no. 1647, and an imperfect specimen of it, collected by *Newberry*

in Macomb's expedition, and named by Torrey *G. Macombii*, is the same. This name should therefore come into use, now that the three species which I had confounded may be made out, thanks to good specimens collected by *Lemmon* in 1880 and 1882, and by *Pringle* in 1884, these all in the southern part of Arizona, while Newberry's specimen is probably from farther north. In Proc. Am. Acad. xvii. 223, I have assigned the reasons for referring all of *Collomia* group back to *Gilia*. This species is more showy than the two following, but less so than *G. Thurberi*, Gray, l. c., with its corollas an inch and a half long, which has been collected by *Greene* in 1881, *Lemmon* in 1882, and *Pringle* in 1884.

Gilia glomeriflora, Benth. in DC. Prodr., so far as we know wholly Mexican, has more filiform foliage, smaller and whitish corollas with pointless lobes, and the stamens wholly included and almost or quite equally inserted; but the last character cannot be absolutely trusted.

Gilia multiflora, Nutt. Pl. Gamb., or the plant which from the station and the description I take to be this species (being New Mexican as well as Arizonian, and occurring in most collections, and probably not perennial), has the foliage and habit of *G. Macombii*, or perhaps is more branching, is more pubescent, and the calyx hirsute; the purplish limb of the corolla somewhat unequally divided (i. e. one sinus deeper); its lobes narrower; the stamens of equal or unequal insertion, conspicuously exserted, and the upper part of the filaments more or less declined and curved, often conspicuously so. I find the ovules to vary from one pair to two pairs in each cell.

Lœselia (Giliopsis) guttata. *L. tenuifoliæ* peraffinis, pariter suffrutescens, glabra; corolla lilacina vel pallida lobis purpureo-guttatis angusto-cuneatis apice tridentatis stamina æquantibus tubo (semipollicari) paullo brevioribus. — Near Hanson's Ranch, northern part of Lower California, *C. R. Orcutt*, Sept. 1884.

Ellisia (Eucrypta) Torreyi. Diffusa, debilis; foliis pinnatipartitis segmentis oblongis sinuato-pinnatifidis vel crenatis, inferioribus sæpe bipinnatifidis; racemis paucifloris; calyce corollam parvam æquante, fructifero capsulam superante. — Yampai Valley, on the Lower Colorado (*Phacelia micrantha?* var. *bipinnatifida*, Torr. in Ives Colorado Rep. Bot. 21); and along the borders of Sonora and Arizona, *Pringle*, 1884. Imperfect specimens of this had been passed as a form of *Phacelia micrantha*.

Phacelia Rattani. *Euphacelia*, *P. malvæfoliæ* peraffinis, minor, gracilis, setis tenuioribus sed urentibus hispida; foliis ovatis ovalibusque

basi nunc subcordatis; spicis laxiusculis; sepalis 4 spathulatis, uno sæpius obovato multo majore; corolla parva (vix ultra lin. 2 longa alba vel purpurascente); staminibus styloque inclusis. — Moist and shady grounds, Lake Co. and northward in California, *V. Rattan*, June, 1884, *Mrs. Layne-Curran*, July, 1884. Grant's Pass, S. Oregon, *Howell.* Seeds barely half the size of those of *P. malvæfolia*, with inner angle acute but less carinate, and the converging sides plane. This was separately discovered by three collectors nearly at the same time; but it first came to hand from Mr. Rattan.

PHACELIA INVENUSTA. *Euphacelia, P. crenulatæ* quoad folia subsimilis, haud graveolens, semi- vel sub-pedalis; foliis omnibus petiolatis oblongis obtusissimis crenato- vel sinuato-paucilobatis nunc lyrato-pinnatifidis adpresso-puberulis; cymis viscidulo-glandulosis absque pilis setiformibus; floribus parvulis; sepalis sursum parum dilatatis; corollis lin. 2 longis; staminibus styloque inclusis; capsula globosa; seminibus ovalibus marginibus incurvis carinaque demum tuberculato-rugosis. — Arizona, on Patagonia Mountains, 1880, *Lemmon* (84, 161), and near Flagstaff, *Lemmon*, 1884; also near Tucson, *Pringle*, 1884, along with *P. crenulata.* The latter is unpleasantly scented (which this is not) and has much larger flowers, with well-exserted stamens and style and usually hirsute pubescence. *P. cærulea*, Greene, also of Arizona, is the nearest to *P. invenusta.*

PHACELIA POPEI, Torr. & Gray, is a good species, as distinct from *P. glandulosa*, under which name it has recently been distributed by A. H. Curtiss (no. 2128). It has short-oval and more pitted seeds, the edges of the pits muriculate-toothed, therefore rougher.

PHACELIA ARIZONICA, Gray. To this no. 1580 of C. Wright's Arizona and New Mexican collection appears to belong.

PHACELIA (EUTOCA) LYONI. Viscido-pubescens; caule pedali sat robusto; foliis et inflorescentia fere *P. glandulosæ;* corolla lato-campanulata, appendicibus semi-ovalibus ima basi filamentis suis accretis; genitalibus haud exsertis; capsula angusto-oblonga polysperma sepalis lineari-spathulatis hispidis et viscosis paullo breviore; seminibus ovalibus (paullo ultra semilineam longis) scrobiculatis. — Island of Santa Catalina off Los Angeles, California, *W. S. Lyon*, 1884. — This is most nearly related to the following, of which a long description has been published, but which still needs a diagnostic character.

PHACELIA IXODES, Kellogg in Bull. Calif. Acad. i. 6. Undique viscido-villosa, graveolens, procera; foliis amplis pinnatipartitis nunc pinnatifidis, segmentis lobisve oblongis inciso-dentatis vel sinuato-pinnatifidis; corolla (cærulescente) lato campanulata, lobis latissimis

rotundatis, appendicibus semi-orbiculatis prorsus adnatis obliquis ima basi staminis accretis; genitalibus parum exsertis; capsula oblonga polysperma sepalis spathulatis parum breviore; seminibus (fere lineam longis) oblongis angulatis asperulo-scrobiculatis. — Cedros Island off Lower California, collected by the late *Dr. Veatch.* All Saints' Bay, Lower California, *H. C. Orcutt.* A coarse species, very clammy and heavy-scented, rather large-flowered. The stamens and style are exserted in the specimens described by Dr. Kellogg, but included or nearly so in those from All Saints' Bay: otherwise no difference is perceived. The root of both these nearly related species is unknown to us. But the latter is said by Dr. Kellogg to be perennial.

PHACELIA (EUTOCA) SAXICOLA. Consors *P. pusillæ*, Torr., e radice annua ramosissima, spithamæa, hirsutula, subviscosa; foliis spathulatis integerrimis in petiolum gracilem angustatis; floribus brevipedicellatis sparsis; sepalis spathulato-lanceolatis corolla oblongo-campanulata cærulea (lin. 2 longa) aut duplo aut paullo longioribus; plicis corollæ angustissimis; capsula ovali-oblonga polysperma; seminibus subglobosis læviusculis. — In crevices of granite rocks, at Kingman's Station, N. W. Arizona, April–May, 1884, *Mr.* and *Mrs. Lemmon.* "The roots, insinuating themselves into crevices, cleave off scales of the rock."

NAMA HAVARDI. (Inter *N. stenophyllum* et *N. Palmeri.*) Pube prorsus molli brevi subcinereum; caule herbaceo robusto ramoso ultrapedali (radice ignota); foliis oblongis acutiusculis basi attenuatis parum venosis; cymulis plurifloris brevi-pedunculatis; corolla (lin. 4–5 longa) hypocraterimorpha sepala linearia sursum vix latiora obtusa paullo superante; filamentis ad medium usque adnatis et sub-alato-marginatis edentatis; seminibus 16 vel pluribus ovoideo-globosis pauci-scrobiculatis. — Western borders of Texas, on alkaline banks of Tornillo Creek, August, 1883, *Dr. V. Havard.* The inflorescence is nearly that of *N. stenophyllum;* the leaves are broader (the largest 2 inches long, including the petiole-like base, and half an inch wide); there are no bristly hairs, but only soft pubescence; the sepals are more decidedly obtuse; and there are no vestiges of teeth to the filaments. — The two following depressed and small-flowered species were discovered and indicated as new species by Mr. and Mrs. Lemmon.

NAMA DEPRESSUM, Lemmon in herb. Annuum, a basi divaricato-ramosum, fere prostratum, pube minuta adpressa molli subcinereum; foliis spathulato-lanceolatis inferne sensim longius attenuatis quasi petiolatis; floribus in dichotomiis brevipedicellatis; corolla angusta purpurascente (lin. 2 longa) sepalis angustis sursum vix latioribus

paullo longiori, limbo parvo; capsula demum deflexa ovali-oblonga torosa; seminibus (lin. $\frac{1}{4}$ longis) ovalibus, testa tenui lævi parum undulata. — Southeastern borders of California, in the Mohave desert, near Fort Mohave, *Mr.* and *Mrs. Lemmon*, May, 1884. Leaves half-inch to an inch long, 2 lines wide. The place of this and the following species in the Synoptical Flora is between *N. Coulteri* and *N. dichotomum*.

Nama pusillum, Lemmon in herb. Annuum, exiguum, a basi ramosum, depressum, molliter pubescens; foliis obovato-spathulatis seu ovatis in petiolum marginatum subito angustatis; floribus in dichotomiis subsessilibus; corolla angusta (sesquilineam longa) roseo tincta extus hirsutula sepalis demum spathulatis paullo longiore, limbo parvo; capsula erecta ovali; seminibus subglobosis, obsolete rugulosis, testa diaphana lævissima. — Same locality and collectors as the preceding. Plants only an inch or so in height; the leaves half-inch or less in length, including the petiole.

Convolvulaceæ.

Convolvulus pentapetaloides, L. A synonym of this South European species, which has found its way to California, probably with grain, is *Breweria minima*, Gray, Proc. Am. Acad. xvii. 228, which came from Lower California, where the advent of this plant was unsuspected.

Solanaceæ.

Lycium exsertum. *L. gracilipedi* inter *Longiflora* proximum, puberulum, subspinosum; foliis spathulatis (majoribus semipollicaribus); pedicellibus gracilibus (lin. 4 longis); calyce angusto-campanulato (lin. 2–3 longo) lobis acutis tubo paullo brevioribus; corolla infundibuliformi semipollicari, tubo proprio calyci æquilongo, fauce elongato, lobis 5 ovato-triangularibus per anthesin reflexis; filamentis insigniter exsertis inferne villoso-tomentosis. — N. W. Sonora, near Altar, March, 1884, *Pringle*.

Lycium Parishii. Inter *L. puberulum* et *L. Cooperi* collocandum, pube foliisque fere prioris; pedicellis gracilibus flore paullo brevioribus (lin. 3 longis); calycis lobis tubo fere æquilongis; staminibus e fauce corollæ exsertis lobis obtusissimis adæquantibus; antheris ovalibus. — Mesas in San Bernardino Valley, S. California, *Parish Brothers*.

Lycium Pringlei. Præcedenti affine, magis glanduloso-pubens; ramis gracilioribus; pedicellis (lin. 2 longis) calyce subæquilongis; calycis lobis oblongis foliaceis tubo suo longioribus corolla violacea

(lin. 4–5 longa) subdimidio brevioribus; filamentis basi crebre barbatis corollæ lobis rotundatis paullo brevioribus.

LYCIUM MACRODON, Gray, the remaining species of the calycose and pentamerous group, has been rediscovered by Mr. Pringle, at a more southern station, namely, within the borders of Sonora. It has remarkably long calyx-lobes, the white corolla tinged with green, and under the ovary an extremely large and deep orange-colored disk.

LYCIUM PALMERI, Gray, would seem to be the *L. quadrifidum* of Dunal.

Scrophulariaceæ.

ANTIRRHINUM SUBCORDATUM. Inter *Prehensilia, A. vaganti* proximium; pube tenuiori; caule robusto (basi ignoto) superne crebre folioso et florifero; ramis prehensilibus copiosis nunc sterilibus nunc parce floriferis; foliis crassiusculis (superioribus) ovatis basi plerumque subcorda arcte sessilibus; floribus fere sessilibus; sepalo postico maximo ovali stylo æquilongo cæteris lineari-lanceolatis longiore; corolla (semipollicari) ochroleuca, fauce ampla; filamentis longioribus apice dilatatis; seminibus favosis alveolis muriculatis. — Stony Creek, Colusa Co., California, *V. Rattan*, June, 1884.

PENTSTEMON HAVARDI. *Eupentstemon, Genuini*, glaber, glaucescens; foliis ovalibus oblongisque coriaceis fere *P. Wrightii;* thyrso nudo elongato virgato racemiformi, verticillastris sæpius 6-floris; sepalis brevibus ovalibus obtusis; corolla aut cærulea aut violacea tubulosa pollicari, labiis lin. 2 longis, postico erecto breviter bifido, antico trilobo patente, lobis rotundatis; filamento sterili filiformi nudo. — Guadalupe Mountains, Western Texas, not far from the Rio Grande, 1882, *Dr. V. Havard.* Apparently the same species (noted as having purple flowers) is no 245 of coll. *Wislizenus*, which is said to have been collected in Mr. Pott's garden at Chihuahua; but the specimen is too incomplete for certain determination. The ticket states that the species is spontaneous near Chihuahua.

PENTSTEMON NUDIFLORUS. *Eupentstemon*, glaberrimus, glaucescens, bipedalis; caule paucifoliato in thyrsum longum virgatum laxiflorum exeunte; foliis ovato-lanceolatis coriaceis integerrimis basi subamplexicauli sessilibus (majoribus tripollicaribus), superioribus dissitis mox in bracteas subulatas parvas pedunculis 3–1-floris gracilibus multo breviores diminutis; corolla (pollicari rubescenti?) e tubo sepalis lato-ovatis (lin. 2 longis) 2–3-plo longiore campanulato-ampliata, labiis lobisque brevibus patentibus; antheris subexsertis, loculis divaricatis oblongis prorsus bilocellatis; filamento sterili tota fere longitudine

piloso-barbato. — La Vergne Park, near Flagstaff, N. Arizona, 1884, *Mr.* and *Mrs. Lemmon.* In the inflorescence and flowers this neat species resembles *P. stenophyllus*, but the inflorescence (fully a foot long) is narrower and more virgate, the corolla smaller, the whole completely glabrous: the leaves are very different; and the pubescence along the whole length of the sterile filament is peculiar.

MIMULUS RATTANI. *Eunanus,* juxta *M. leptaleum* collocandus, viscido-pubescens, a basi ramosus, ultra-spithamæus; foliis oblongis sessilibus, imis basi angustatis superioribus flores subsessiles haud superantibus; corolla roseo-purpurea in calyce ventricoso subæqualiter 5-dentato fere inclusa, limbo parvulo tubo cum fauce infundibulari 3-4-plo breviore, lobis subæqualibus, posticis ad medium fere connatis; capsula lanceolata acutata coriacea e calyce amplo subdimidio exserta. — Mountains of Colusa Co., N. W. California; under *Adenostoma* bushes, *Volney Rattan*, June, 1884.

MIMULUS EXIGUUS. *Mimuloides* quoad calycem, facie *M. rubelli,* annuus, tenellus, fere glaber, diffuse ramosus; foliis (lin. 2–3 longis) subspathulatis sæpius parce denticulatis sessilibus; pedunculis capillaribus elongatis; calyce brevi-campanulato subturbinato æqualiter 5-dentato haud angulato vix nervato sesquilineam longo corolla rubella minima vix dimidio breviore; capsula ovali submembranacea calycem æquante, valvis axi placentæ indivisæ adhærentibus. — Mountains of Lower California, in the northern part, near Hanson's Ranch, *H. C.* and *C. R. Orcutt.* A peculiar and aberrant little species.

PEDICULARIS HOWELLII. *Rhyncholophæ, Proboscideæ,* glabra (spica excepta); caule pedali simplici infra medium aphyllo superne usque ad spicam compactam cylindraceam folioso; foliis oblongis, inferioribus brevi-petiolatis sublyrato-pinnatifidis partitisve (lobis 3–9 oblongis subserratis), summis sæpe integris; bracteis foliaceis ovatis acuminatis margine inferne villosis flore parum brevioribus; calyce campanulato longe parceque villoso 5-dentato, dentibus ovatis subintegerrimis, posticis altius connatis; corolla pallida tubo calycem superante, rostro roseo tincto longiusculo incurvo (eo *P. compactæ* simili sed apice truncato parum latiori), labio parvo. — Siskiyou Mountains, N. California, *Howell*, 1884. Belongs to the group of *P. compacta* and *P. uncinata*, but with quite different foliage and bracts, and with a very small under lip.

APHYLLON COOPERI. *A. Ludoviciani* et *A. multiflori* consors; caule spithamæo ad pedalem e basi tuberosa spicato-multifloro; floribus inferioribus pedicellatis, superioribus sessilibus; calycis lobis lanceolatis capsulam æquantibus; corolla violacea ($\frac{2}{3}$-pollicari) pro-

fundius bilabiata, labio postico semibifido, antico tripartito, lobis lanceolatis acutis; antheris ante dehiscentiam glabris; stigmate infundibuliformi-dilatato fere orbiculato. — In the Mohave district, S. E. California and adjacent Arizona; first collected at Fort Mohave by *Dr. J. G. Cooper*, in 1860, who states that the tuber-like base is bitter, but is eaten by the Indians; collected at Camp Lowell, Arizona, by *Parish* and by *Lemmon*, 1881, also, in the same year, in the Santa Catalina Mountains, by *Pringle*, and distributed as *A. Ludovicianum*, var. *Cooperi*. But it is evidently a distinct species.

Acanthaceæ.

DICLIPTERA PSEUDOVERTICILLARIS. Inter *Platystegias et Sphenostegias* media, annua, a basi ipsa ramosa et florens, fere glabra, vix pedalis; caulibus ramisve diffusis; foliis caulinis inferioribus ovatis acuminatis (ultra-pollicaribus) longe petiolatis, superioribus multo minoribus ovato-ellipticis brevipetiolatis involucris axillaribus subsessilibus foliiformibus plerumque æquilongis; bracteis involucri primum patentibus deltoideo-rotundatis obtusissimis retusisve (raro mucronulatis), basibus subito contractis in cyathum angustum sæpius coalitis; corolla brevi involucrum haud superante; seminibus processibus subulatis sub lente setuliferis muricatis. — N. W. Sonora, Mexico, in the valley of the Altar, April, 1884, *Pringle*. And imperfect specimens of seemingly the same species, with the narrowed bases of the involucral bracts mostly distinct, were collected by *Thurber*, in 1851, at Bacuachi, in the same district. In Mr. Pringle's specimens through all the upper part of the stem the involucres (which are shorter than the internodes), one in each axil, are about the length of the subtending leaves, their two leaves quite as broad as they, and at first open so as to give a verticillate appearance to most of the foliage. I take this opportunity to distinguish two species of *Dicliptera* of the Arizono-Mexican region which have been confounded.

DICLIPTERA RESUPINATA, Juss. Caule laxe ramoso e radice annua; foliis ovatis vel ovato- seu oblongo-lanceolatis longiuscule petiolatis; involucri bracteis cordato-rotundis; seminibus ut in præcedente muricatis. — I follow Nees in applying this name to an annual plant, and in supposing that Cavanilles was wrong in taking his *Justicia sexangularis* for a perennial, as also was Vahl in following him. I also suppose that the character, well represented by Cavanilles, of some subsessile and some long-pedunculate involucres, is not constant, the former being mostly wanting in our specimens. From the habitat it is not so probable that the following species was known a hundred

years ago. We have it in Coulter's collection (no. 557 of the "Californian" collection, doubtless North Mexican); from Magdalena, Sonora, no. 1028 of Thurber's collection, and on the Yaqui River, from Palmer; also from Lower California, collected by Xantus; but not from any station within the United States.

DICLIPTERA TORREYI. Caulibus e caudice perenni lignescente plurimis simpliciusculis sæpius strictis circiter pedalibus; foliis omnibus lanceolatis cum petiolo brevi sub-sesqui-pollicaribus; involucri bracteis cordato-rotundis sæpius emarginatis; seminibus papillis acutis nudis scabris. — *D. resupinata*, Torr. Bot. Mex. Bound. 125; Gray, Syn. Fl. ii. 331, maxima pro parte. — Arizona, *Thurber, Wright, Schott, Rothrock, Lemmon, Pringle*, &c. The involucres seem always to be pedunculate, more or less; the peduncles are either simple and naked, or bibracteate and bearing either one or two to four umbellate secondary peduncles.

Labiatæ.

SALVIA LEMMONI. *Fulgentes, S. Grahami* peraffinis, undique puberula; caulibus simpliciusculis (pedalibus) herbaceis e basi suffruticosa; foliis subdeltoideo- vel oblongo-ovatis inæqualiter serrulatis, basi truncata vel parum cuneata; bracteis parvis canescentibus; calyce angustiore atomifero; corolla (pollicari) angustiore magis exserta minus ventricosa. — S. W. Arizona, in the Huachuca Mountains, *Lemmon, Pringle.* In Lemmon's collection of 1881, this was passed as a form of *S. Grahami*, which varies much; but the specimens collected by Pringle in 1884 confirm the moderate distinctions. The latter have smaller and narrower leaves and still less ventricose corolla. Only the base or caudex, from which the nearly simple stems arise, is lignescent. It would be an acquisition to the gardens.

CEDRONELLA BREVIFLORA. *C. pallidæ*, Lindl., nimis affinis, pariter foliis omnibus subcordatis petiolatis obtusis, sed minutissime puberula; foliis floralibus verticillastra compacta subsuperantibus; dentibus calycis (lin. 3–4 longis) attenuato-subulatis corollam parvam subæquantibus. — S. Arizona, in the Santa Rita Mountains, alt. 7,000 feet, *Pringle.* The specimens seem to be in normal condition; but the corolla is very small and inconspicuous, the limb hardly surpassing the calyx-teeth, the lips barely a line long.

Var. HAVARDI. Thyrso capituliformi; calycis dentibus latioribus; corolla lin. 4–5 longa e calyce semi-exserta, labiis lineam longis. — Cliffs and ravines of the Chisos Mountains, W. Texas, on the borders of Chihuahua, *Dr. V. Havard.*

Cedronella pallida, Lindl. Bot. Reg. 32, t. 29, is known only from the figure and description. It was raised from seeds, probably from Chihuahua; and if the species varies as widely as does *C. cana*, Hook., it may include the plants above characterized. But Lindley's figure makes the stem and calyxes hirsutely pubescent, the inflorescence open, the flowers nearly an inch long, and the lower lip of the corolla 3 or 4 lines long.

Cedronella cana, Hook., as to the originally published form, we cannot well distinguish from *C. Mexicana.* But in New Mexico it runs into a form, var. lanceolata (collected by *Dr. Rusby* and by *G. R. Vasey*), with small, narrowly-lanceolate, and entire leaves, which differ most widely from *C. Mexicana.*

XIII.

NOTES ON SOME SPECIES OF GYMNOSPORANGIUM AND CHRYSOMYXA OF THE UNITED STATES.

By W. G. Farlow.

Communicated February 11th, 1885.

In a paper published in the Anniversary Memoirs of the Boston Society of Natural History in 1880, I gave an account of my attempts to show, by means of cultures, the relationship of the *Gymnosporangia* found near Boston to the different forms of *Ræstelia* occurring in the same region; and also, by reviewing the geographical distribution of the species of both genera in the United States, to ascertain the probabilities of the genetic connection of different forms of the genera in question. My cultures, however, were not successful in proving the direct relationship of any given *Gymnosporangium* with any given *Ræstelia;* but, as the subject is of importance, both from a biological and practical standpoint, I have made further attempts to see whether a more definite result could be reached.

The method of culture employed was the following. Specimens of different species of *Gymnosporangium* were gathered early in May, before the spores had begun to germinate, and while the spore masses were flat and not swollen in gelatinous protuberances, as is the case when they are moistened by showers. The specimens were then placed in watch-glasses under moistened glasses, each species by itself, when the spore masses soon expanded, and the spores began to germinate. It was in this way easy to arrange so that the spores of the different species were kept pure, — a fact confirmed by microscopic examination. As the spores germinated, the sporidia, of a bright orange color, dropped into the moist watch-glasses, and were used at once for infecting the desired plants. Two kinds of material were used. The first consisted of leaves of different *Pomaceæ*, which were freshly gathered in the Botanic Garden of Cambridge, and at a distance from any species of *Juniperus* which could have been infested by a *Gymnosporangium.* The leaves were placed on moistened glass

slides and arranged on zinc stands under bell-glasses. The sporidia were then carefully dropped upon the leaves, which were immediately covered by a bell-glass. The leaves under each glass were sown with the sporidia of but one species, and subsequently, when it was necessary to remoisten the slides, the bell-glasses were removed for a moment only, and at no time were the leaves under more than one bell-glass exposed. I also used a number of small seedlings of *Pomaceæ*, each pot being covered by a glass receiver. The seedlings were supposed to be in a healthy condition, but, to serve as a check, a number of similar seedlings were kept on which no sporidia were sown. The young plants were inoculated, either by dropping the sporidia upon them, or, in cases where the leaves were not in such a position as to retain drops well, small pieces of the gelatinous spore-masses were placed on them, it first being ascertained that the spores had begun to germinate. After three or four days it was necessary to remove the remains of the gelatinous masses in order to prevent moulding. After the lapse of a week, at which period the germinal tubes, if ever, must have made their way into the leaves, I attempted in a few cases to remove the glass receivers and continue the cultures in the open air. This, however, was impossible, for the plants wilted to such an extent that I was obliged to keep them constantly covered. European experimenters usually expose their cultures to the air after a few days, but it is doubtful whether this can be done in our climate except in the most favorable cases, so great and sudden are the changes of moisture and temperature.

The following statement shows the results of the cultures made in May and June, 1883. I was unable to continue my cultures, unfortunately, in the spring of 1884, as I had intended. The names of the species with which experiments were made are those given in my paper above mentioned, in which the synonymy is given.

I. GYM. FUSCUM *var.* GLOBOSUM.

May 18. Sporidia sown on
5 seedlings of apple.
3 leaves of *Cratægus oxyacantha.*
3 leaves of apple.
4 leaves of *Amelanchier Canadensis.*

May 26. Spermogonia appeared on four of the apple seedlings.

May 28. Spermogonia appeared on the remaining apple seedling, and very abundantly on the three leaves of *Cratægus.*

June 1. Spermogonia appeared on one leaf of apple.

June 8. The spermogonia on leaves named still visible, but the leaves had become so mouldy that there was no hope of the development of æcidia, and the cultures were abandoned.

II. Gym. macropus.

May 18. Sporidia sown on
5 seedlings of apple.
4 leaves of apple.
3 leaves of *Amelanchier Canadensis.*
3 leaves of *Cratægus oxyacantha.*

May 28. Soon after the sowing, the leaves of apple seedlings became mottled, but no spermogonia were plainly seen until the 28th, when they appeared on all the five seedlings.

June 8. Culture abandoned, as the leaves were all mouldy.

III. Gym. clavipes.

May 18. Sporidia sown on
5 seedlings of apple.
4 leaves of apple.
4 leaves of *Amelanchier Canadensis.*
3 leaves of *Cratægus oxyacantha.*

May 23. Spermogonia appeared on one leaf of *Amelanchier.*
May 24. Spermogonia appeared on one seedling apple.
May 26. Spermogonia on two more apple seedlings.
May 28. Spermogonia on two more leaves of *Amelanchier.*
June 10. Leaves mouldy and culture abandoned.

IV. Gym. biseptatum.

May 19. Sporidia sown on
5 seedlings of apple.
3 leaves of apple.
4 leaves of *Amelanchier Canadensis.*
3 leaves of *Cratægus oxycantha.*

May 28. Spermogonia appeared on three *Amelanchier* leaves.
June 5. Leaves mouldy and culture abandoned.

V. Gym. Ellisii.

May 23. Sporidia sown on two seedlings of apple.

May 29. As the previous sowing produced no result, owing possibly to the sporidia not being sufficiently abundant, five seedlings of apple, including the two mentioned above, were sown with fresh material. No result.

Comments on Cultures I.–V. — The cultures I.–III. were started on the same day. No. IV. was not started until the following day, as a microscopic examination showed that the spores were not germinating freely until May 19th. In No. V. the sporidia were not produced in sufficient quantity for sowing until May 23d, and even then they were scanty, so that fresh specimens were collected, which produced a sufficient quantity of sporidia for sowing on May 29th. At the time when the five cultures were started, the only seedlings of a suitable size which could be procured were those of apple; but as it was easier to obtain pure spores of the species of *Gymnosporangium* on the date named, the cultures were then started, and a second series of cultures were arranged later, when other seedlings could be procured. The spores for the second series were from specimens selected with care, so as to be as pure as possible; but from the later date, and the fact that there had been showers which had swollen the masses of spores, the possibility of the accidental mixture of the spores of one species with those of another could not be guarded against with the same degree of certainty as in the preceding series. It may be remarked that in 1883 the season was backward, and the *Gymnosporangia* did not mature as early as they frequently do. In both series of cultures the control plants remained free from spermogonia. Where the statement is above made, that the cultures were abandoned on a given day, it should be understood that the statement applies only to the leaves under bell-glasses. In the cases where spermogonia appeared on the leaves of seedlings, the cultures were kept for a longer period; but these cases will be referred to again later.

VI. Gym. fuscum *var.* globosum.

May 25. Sporidia sown on
2 seedlings of *Cratægus Douglasii.*
1 seedling of *Pyrus* sp. cult.
May 31. Spermogonia appeared on all the seedlings.

VII. Gym. macropus.

May 25. Sporidia sown on
2 seedlings of *Cratægus Douglasii.*
1 seedling of *Pyrus* cult.
June 5. Spermogonia appeared on one *Cratægus.*

VIII. Gym. clavipes.

May 25. Sporidia sown on
 1 seedling of *Cratægus Douglasii.*
 1 seedling of *Pyrus* cult.
May 31. Spermogonia appeared on seedling of *Pyrus.*

A third set of experiments consisted in placing fresh shoots of *Amelanchier Canadensis* and *Pyrus arbutifolia* in jars of water, covering them with receivers, and sowing on the leaves the sporidia of *G. macropus*, *G. clavipes*, *G. biseptatum*, and *G. Ellisii.* The cultures were started on May 30th, with the following result. On June 4th, spermogonia appeared on both *Amelanchier* and *Pyrus arbutifolia* sown with the sporidia of *G. macropus* and *G. clavipes,* and on *Amelanchier* sown with *G. biseptatum.*

As the sporidia of *G. biseptatum* and *G. Ellisii* proved more refractory than those of other species, two supplementary cultures were made, as follows: —

Gym. biseptatum.

May 29. Sporidia sown on
 5 leaves of *Pyrus arbutifolia.*
 3 leaves of *Nesæa verticillata.*
 Young shoots of *Nesæa, Amelanchier,* and *Pyrus arbutifolia.*
May 31. Spermogonia appeared on leaves of *Amelanchier* shoot.

Gym. Ellisii.

May 29. Sporidia sown on
 5 leaves of *Pyrus arbutifolia.*
 3 leaves of *Nesæa verticillata.*
 Young shoots of *Pyrus arbutifolia* and *Nesæa.*
 No spermogonia.

In these last two cultures I was led to try the leaves of *Pyrus arbutifolia* because the form known as *Ræstelia transformans* had been usually found by me in districts near *Cupressus thyoides*, on which *G. biseptatum* and *G. Ellisii* are parasitic. As I had never succeeded in getting spermogonia from sowings of *G. Ellisii* on *Pomaceæ*, it occurred to me that possibly the æcidial form of that species might be found on a host of some other order, and, in the cedar swamps where *G. Ellisii* is found, *Nesæa* abounds and is not infrequently infested with the

striking *Æcidium Nesæa* Gerard. No spermogonia, however, were developed. At the date when the culture was started the leaves of *Nesæa* were not fully expanded; but they soon opened, and the shoots grew rapidly in the house.

In attempting to draw any conclusion from the statements previously given, we may exclude any consideration of *G. Ellisii*, for neither in 1883 nor in previous years did spermogonia appear in any cultures made with that species. The species used include all the members of the genus *Gymnosporangium* known in the Eastern United States except *G. clavariæforme* DC., of which I could not procure fresh material in season, *G. conicum* DC., and the typical form of *G. fuscum* DC. The last two forms require further study, and it is not certain that the few specimens referred to them should not be placed in other species. The results of the cultures may be summarized as follows: —

Spermogonia appeared after sowing the sporidia of

G. fuscum var. *globosum* on seedling apples, on *Cratægus oxyacantha* (very abundant), on *C. Douglasii*, and on apple leaves under bell-glass. In cultures of previous years, also on *C. tomentosa.*

G. macropus on apple seedlings, on *C. Douglasii*, and on shoots of *Pyrus arbutifolia* and *Amelanchier.* Also in previous cultures on *C. tomentosa* and *Amelanchier.*

G. clavipes on apple seedlings and shoots of *Pyrus arbutifolia* and *Amelanchier.*

G. biseptatum on *Amelanchier* leaves and shoots, and previously on *C. tomentosa.*

From the above it will be seen, not only that the sporidia of different species of *Gymnosporangium* when sown on the same host-species were followed by the appearance of spermogonia, but also that the sporidia of each species was followed by spermogonia when sown on several different host-species. The perplexity is all the greater, because the host-plants as a rule are species which, in nature, are attacked by more than one *Ræstelia*, and in the case of the cultures the species could not, of course, be determined by the spermogonia above. In this connection, a word may be said on the production of æcidia by cultures. In the case of leaves kept on slides under glasses, it is of course out of the question to expect to be able to keep the leaves free from mould long enough for æcidia to develop. For tentative experiments, where one wishes to form some notion as to the probability of the connection between certain forms, they do very well. But it may be asked why

æcidia were not produced on the seedlings on which spermogonia appeared. I did my best to keep the young plants alive, but they were all dead by the end of June. Had it been possible to remove the glasses and expose them to the air, they might have done better; but in exposing them to the air, one should not forget that he is also exposing them to the risk of contact with spores from without. On some of my seedlings the spermogonia were very abundant, and it may be urged that, in such cases, the seedlings were destroyed by the violence of the disease itself before the æcidia could form. The same objection, however, will not apply to the seedlings on which the spermogonia were scanty. Yet the latter died, like the former. The spermogonia appeared well marked on some of the leaves, which after some days dropped off, and were followed by fresh crops of spermogonia on other leaves. In the absence of æcidia, can we infer anything from the spermogonia?

Before trying to answer this question, I must say that I attach very little value to what I have called the third series of cultures, — those in which shoots of *Amelanchier* and *Pyrus arbutifolia* were placed in glasses and the sporidia dropped on the leaves, — for the following reasons. The spores were gathered late in the season, after repeated showers, so that a mixture of the spores of different species could not be avoided with approximate certainty; and, furthermore, the spermogonia were very few in number, did not always develop on the spots where the sporidia were dropped, but on remote parts of the leaves, and, in one case they appeared so soon after the sowing — two days — that it is much more probable that the shoots were already infected with the *Ræstelia* before the sowing, than that the spermogonia came in any way from the growth of the sporidia. I think it well, then, to omit from present consideration the cases where spermogonia appeared on shoots of *Amelanchier* and *Pyrus arbutifolia* in the cultures of 1883.

As in previous cultures, so in those of 1883, spermogonia appeared on more hosts, and in greater abundance, after sowing the sporidia of *G. fuscum* var. *globosum* than in the case of the other species. The poorest result came from *G. biseptatum*, if we except *G. Ellisii*, in which there was no result at all. In cultures previous to 1883, in which leaves and seedlings of *Cratægus tomentosa* were used, spermogonia appeared on that host after sowing *G. macropus*, *G. fuscum* var. *globosum*, and *G. biseptatum*. *G. clavipes* was not sown on *C. tomentosa*, as spore material could not be obtained at the date of the cultures. It may, perhaps, be asked whether the *Cratægus* leaves were

not infected with a *Ræstelia* before the sowings. Considering the abundance of *Ræstelia* on *C. tomentosa* in this region, such is very likely to have been the case, but, as far as I could tell at the time, the leaves were healthy. For the sake of the argument, let us omit the cultures on *C. tomentosa*, arbitrarily assuming that there was previous infection.

We have left the fact that *G. biseptatum* was followed by spermogonia on *Amelanchier Canadensis* only. Our only *Ræstelia* growing on the leaves of *Amelanchier* and not found on other hosts is *R. botryapites*, found only on the eastern coast from New England southward, and this it will be noticed is also the range of *G. biseptatum.**

Turning to *G. fuscum* var. *globosum*, we find that sowings of its sporidia on apples, and on *Cratægus oxyacantha* and *C. Douglasii*, were followed by spermogonia, especially on *C. oxyacantha*, where they were very abundant. The result of the sowings of this species are, then, compared with other cultures, an abundance of spermogonia on *C. oxyacantha* and an absence of them on *Amelanchier*. Of the *Ræsteliæ* growing near Cambridge, *R. aurantiaca* occurs on species of *Cratægus* and apples; but I have not found it on *Amelanchier*, although according to Peck it occurs on that host in New York. The forms included under *R. lacerata* and *R. penicillata* are common on *Amelanchier* near Cambridge, while *G. globosum* was not followed by spermogonia on that host. The *G. globosum* ranges from Canada to Wisconsin and South Carolina. *Ræstelia aurantiaca* extends from New England to Arkansas, where it was found on a species of *Cratægus* by Prof. F. L. Harvey. The distribution of the *Ræstelia* and that of the *Gymnosporangium* are about the same. The *Ræstelia* bears its æcidia usually on the young fruit and stalks, while the spermogonia are borne on the leaves. Hence, in cultures of leaves unaccompanied by young fruit, even if there really is a connection between *G. globosum* and *R. aurantiaca*, one would naturally expect to get only spermogonia. Remembering that the æcidia of *R. aurantiaca* develop on the berries rather than the leaves, I have tried to obtain the young berries for my cultures; but I have never yet found any berries formed at the time when the *Gymnosporangia* were ripe.

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* In my paper on *Gymnosporangia* this species is also given on *Libocedrus* in California, on the authority of Harkness and Moore. I have never examined Californian specimens which, judging from the host, may belong to a distinct species. *G. speciosum* Peck, nearly related to *G. Ellisii*, occurs on *Juniperus occidentalis* in Colorado.

The sporidia of *G. macropus*, when sown, were followed by spermogonia on apple seedlings, on seedlings of *Cratægus Douglasii*, and on leaves of *Amelanchier*. As distinguished from the last species, where the spermogonia appeared most abundantly on species of *Cratægus*, the present shows the growth of spermogonia on apples and *Amelanchier*, and less abundantly on *Cratægus*. *G. clavipes* was followed by spermogonia on apple seedlings, but not on *Amelanchier*. With what two *Ræsteliæ* the two last-named *Gymnosporangia* might be associated one cannot safely guess. Considering the distribution in nature, one would be inclined to suggest *R. transformans* * as belonging to *G. clavipes*, and some form of *R. lacerata* or *R. penicillata* as belonging to *G. macropus*. But it is well not to encroach upon the boundaries of pure imagination.

Rejecting what I have called my third series of cultures on shoots of *Amelanchier* and *P. arbutifolia*, on the ground that they were conducted under conditions not conducive to accuracy, — which I consider to have been the case, — and assuming that the *Cratægus tomentosa* employed in cultures previous to 1883 was already infected with a *Ræstelia* when the experiments began, — which might or might not have been the case,† — the conclusions to be drawn are, that, —

1. The æcidium of *G. biseptatum* is probably *Ræstelia botryapites*.

2. The æcidium of *G. globosum*, to be kept distinct from *G. fuscum*, is possibly *Ræstelia aurantiaca*.

3. The æcidium of *G. macropus* is to be sought among the *Ræsteliæ* growing especially on apples and *Amelanchier*.

If it be admitted that the *C. tomentosa* was not previously infected, but that the development of spermogonia was the result of the sowings, then it follows that the sporidia of our four species in question may produce spermogonia indiscriminately on one and the same host, or on different hosts, in a way which is not paralleled in nature by the species of *Ræstelia*. There is nothing impossible or illogical in this conclusion; but in accepting it we must bear in mind that we must reject the observations of Oersted, and all who have only succeeded in developing spermogonia without æcidia, but have neverthe-

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* *G. clavipes* has been found by Holway in Iowa, and Trelease doubtfully refers to *R. transformans* a spermogonial form, whose æcidia were not seen, found on *P. arbutifolia* in Wisconsin. There is need of further information as to the western limits of both these forms.

† See my paper on Gymnosporangia, pp. 36, 37.

less drawn definite conclusions with regard to the connection between certain teleutosporic and æcidial forms.

Finally, it may be urged that, in all the cases where spermogonia followed the sowings of sporidia, their development was not a result of the sowings, but proceeded from the mycelium of some *Ræstelia* already in the material used. That this was the case in the shoots of *Amelanchier* and *P. arbutifolia* I think was probably true, and the same may have been true in case of the *C. tomentosa*, although I am not prepared either to admit or deny the fact. Admitting the theory of previous infection, however, how are we to explain the case of the *C. oxyacantha*, on the leaves of which spermogonia abundantly followed the sowing of the sporidia of *G. globosum*, but did not appear after the sowing of other species? I must admit that I am much perplexed to explain the frequency of spermogonia in some cases and their absence in others, and the failure of infected seedlings to develop æcidia, or even to show the least traces of them. I should be the last to claim that my experiments were in any sense conclusive, but, on the contrary, recognize their incompleteness, and in some respects their contradictory character. My cultures are only significant in so far as they show more plainly difficulties to be avoided, and the general direction in which one must work to reach a successful result, if such a result is ever to be reached, in the study of the development of our *Gymnosporangia*.

In Appalachia, Vol. III. pp. 239–243, I gave an account of the *Peridermia* of the White Mountains, and stated that the species which occurs on the dwarf form of *Abies nigra* resembles *P. abietinum* (A. & S.), which has in Europe been associated with *Chrysomyxa Rhododendri* and *C. Ledi* as an æcidial form. At the time of my visit to the White Mountains, in August and September, no species of *Uredineæ* was found either on *Rhododendron Lapponicum* or *Ledum latifolium*. As Mr. Edwin Faxon was about to make a botanical excursion to the White Mountains in June and July of 1884, I asked him to examine the *Rhododendron* and *Ledum* on Mt. Washington, to ascertain whether a *Chrysomyxa* occurred on those hosts early in the season. With his accustomed acuteness, Mr. Faxon succeeded in finding a form on *Ledum*, which appears to have been common in some spots in July, but which rapidly disappeared, as the early specimens had an abundance, and the later but little, of the fungus. I visited the locality at the head of Tuckerman's Ravine, where the fungus

was found by Mr. Faxon in July, but at the time of my visit, the second week in August, not a trace of the fungus was to be found, either on the living or fallen leaves of *Ledum*.

The first specimens received from Mr. Faxon were collected on Mt. Washington in June. On the upper surface of the leaves were small blood-red pustules, which a microscopic examination showed to be undistinguishable from the teleutosporic condition of *Chrysomyxa Ledi* (A. & S.). In July other specimens were received from Mr. Faxon where no teleutospores were found, but there was an abundance of a uredo form which presented two different aspects. On the upper side of the leaves, in dark discolored spots, a small number of sori were grouped, generally more or less circularly. Sections showed orange-colored spores with decidedly roughened epispores surrounded by a rim of densely packed cylindrical filaments composed of several cells, the whole surrounded by the ruptured epidermis in form of a cup. The spores were produced in small numbers in chains, but at maturity became free, and were then globose or broadly elliptic, measuring 24–38 μ by 20–26 μ. This epiphyllous form is certainly the *Uredo ledicola*, Peck, of which, through the kindness of Mr. Peck, I have been able to examine an authentic specimen.

In some sections I also found sori on the under side of the leaves. They could scarcely be detected by the eye, owing to the densely tomentose character of the under side of the leaves; but I afterwards noticed that, when small yellowish spots were seen on the upper surface of the leaves, the sori could be found beneath. In a comparatively small number of cases sori were found on both sides of a leaf, but generally this was not the case. In Mr. Faxon's collections the epiphyllous form was more abundant than the other. The two may be equally abundant in nature; but as the epiphyllous form is much the more striking to the eye, it naturally follows that the epiphyllous form would be found more abundantly in collections. In general, the developments of the epi- and hypo-phyllous forms was the same, but there was a constant difference in the mature forms. The sori of the hypophyllous form, instead of being in the shape of widely-opened cups, scarcely sunk at all below the level of the epidermis, looked more like partially immersed conceptacles with slightly contracted orifices, whose outer portion projected beyond the epidermis. The spores also were distinctly narrower and more acutely elliptical, measuring 24–31 μ by 12–19 μ, and the epispore was less rough.

I think that there can be no doubt that the hypophyllous form is the uredo of *Chrys. Ledi*, as it answers closely to the descriptions of

De Bary * and Schroeter,† and to European specimens which I have examined. In Europe it is said to occur only on the under side of the leaves, although Schroeter mentions its occurrence on petioles and young stems of *L. palustre.* Mr. Faxon's specimens consisted of leaves of *L. latifolium* without stems. Schroeter states that he has seen a small specimen from Labrador on *L. latifolium* which was the same as the form on *L. palustre,* but no mention is made of epiphyllous sori. The fungus is also said by Rostrup ‡ to have been found on *L. palustre* in Greenland. Whether our epiphyllous form should be considered distinct from the hypophyllous, must, for the present, remain uncertain. I found the differences stated above constant in all the specimens I examined, and they were not few in number. It may be that the two forms are modifications of the same species depending on the different structure of the upper and under side of the leaves, but the differences are certainly greater than those of many forms which are regarded as distinct by good mycologists. It is, in all events, interesting to know that we have in the White Mountains both the uredo and teleutosporic forms of *Chrys. Ledi* growing in close proximity to *Abies nigra* in regions where it is badly infested with a *Peridermium* which, as stated in my paper already referred to, I am unable to distinguish from *P. abietinum,* one form of which is said by De Bary, in his exhaustive paper on the subject, to be the æcidium of *Chrys. Ledi.* The teleutospores were found only in the first set of leaves collected by Mr. Faxon, it will be remembered, while the uredo was collected later. The finding of the teleutospores before the uredo may, in this case, have been merely accidental, and does not show that the uredo was developed later than the teleutospores. Cases have, however, been cited by De Bary, in which the uredo certainly did not develop until after the teleutospores.

In this connection it should be noticed that a new *Æcidium pseudocolumnare* from the Black Forest has been described by Prof. J. Kuehn, in Hedwigia, November, 1884. The species is said to be characterized by having white spores, and one is inclined to ask whether this may not be the same as *Peridermium balsameum* Peck, of the White Mountains and the Adirondacks, which is distinguished from *Æ. columnare* by having white spores.

Besides our common *Chrysomyxa* on *Pyrola,* a species was found on *Abies Canadensis* at Chebacco Lake, Essex Co., Mass., by Mr.

* Bot. Zeit., xxxvii. 802.

† Beitr. zur Biol. der Pflanzen, iii. 52.

‡ Revue Mycologique, vi. 210.

A. B. Seymour, in June, 1883. This is probably the same as the *C. Abietis* of Europe, although, as the spores were not quite ripe, one cannot be certain. If there is a difference, it is to be found in the fact that the teleutospores are arranged in threads which branch less than in the European form. But at a later stage of development this supposed difference might disappear. At the same time and place Mr. Seymour found another interesting species of *Uredineæ* also on *Abies Canadensis*, not on the same branches as the species last mentioned, nor on the same trees, as far as can now be ascertained. Spermogonia were abundant on both sides of the leaves, on whose under surface were elliptical or elongated sori of a pale yellow color, arranged in two rows parallel to the midrib.

The spores were globose or somewhat elliptical, about 13–17 μ in length, and appeared to be borne in chains composed of a small number of spores. It is possible that this form is *Cæoma Abietis-pectinatæ* Rees, of which I have seen no specimens. From the description of Rees, however, his species has larger spores than ours, and no mention is made of spermogonia. It may be well to designate our form under the name *Cæoma Abietis-Canadensis*, until more exact information can be obtained. Prof. J. Macoun has found the interesting *Melampsora sparsa* Winter on *Arctostaphylos alpina*, on the island of Anticosti. Visitors to the White Mountains should search for the fungus there.

XIV.

CONTRIBUTIONS TO AMERICAN BOTANY.

By Sereno Watson.

Communicated January 14th, 1885.

1. *A History and Revision of the Roses of North America.*

History. — Perhaps the earliest notice of our wild roses is found in the account of Gosnold's voyage in 1602, where the "eglantine" is noted among other plants growing on Cuttyhunk. Higginson (1630) and Josselyn (1672) also make mention of wild "single damaske roses" in New England, "verie sweete." The first botanist to mention an American species is Parkinson, in his *Theatrum Botanicum*, in 1640, where he describes his "*Rosa sylvestris Virginiensis;* the Virginia Bryer Rose," with "divers as great stemmes and branches as any other Rose, set with many small prickles and a few great thornes among them, the leaves very greene and shining, small and almost round." He does not state upon what materials his description was based, but, as it accords rather more nearly with *R. lucida* than with any other species, they were probably from New England, which was included in the region then known as Virginia. The name and essentially the same description are given by Ray in the *Historia Plantarum* (1693), but without any additional information.

The next description is by Dillenius, in the *Hortus Elthamensis* (1732), of a species introduced into England by James Sherard in 1726, which he figures and describes under the phrase "*Rosa Carolina fragrans ; foliis mediotenus serratis.*" From the name it may be inferred that it was originally from the Southern States, and it may be quite clearly identified with the *R. humilis* of Marshall (the later *R. parvifolia* of Ehrhart). He also describes and figures a second species as raised by Sherard from seeds received from New England. This, however, is evidently not an American rose, but European, as was perceived by Linnæus, who made it the basis of his *R. pendulina.* Too much confidence in Dillenius's statement of its origin led later botanists into much needless trouble in attempting upon no other ground to retain it among American species.

In 1736 Clayton sent two roses to Gronovius from Virginia, one as a Dog Rose, "*Rosa canina*," the other as a "Sweet Bryar," which were published by Gronovius in 1739 in the *Flora Virginica* under Clayton's exceedingly brief descriptive phrases. Linnæus, whose good judgment led him to be very prudent in recognizing species in this genus, in the first edition of his *Species Plantarum* (1753) makes no reference to these species of Gronovius, nor to any but those of Dillenius, and solely upon the figure and description of the "*Rosa Carolina fragrans*" of the latter made his original *Rosa Carolina.* In the *Systema Naturæ* of 1760, however, and still more fully in the second edition of the *Species Plantarum* (1762), he redescribed the species from specimens raised in the Upsal Garden; but, noticing the discrepancies, he now cited Dillenius with a doubt. The specimens preserved in the Linnæan herbarium satisfactorily identify this first established species, as Linnæus here and always afterward defined it, with the *R. Carolina* as it was figured by Wangenheim (in 1787) and others, and as it has long been generally understood in this country.

Miller, who was the authority of his day upon the cultivated plants of England, in the seventh edition of his *Gardeners' Dictionary* (1759) described the "Wild Virginia Rose, kept in gardens for the sake of variety, and growing naturally in Virginia and other parts of North America," and, considering it the same as the *Rosa sylvestris Virginiensis* of Parkinson and Ray, he adopted their specific phrase, and accordingly in the next edition (1768) named it after the Linnæan method *Rosa Virginiana.* It is impossible to identify it from the description. The name was afterward taken up by DuRoi (1771 and 1772), Wangenheim (1787), and by Gmelin (1796), and applied by them to a form of *R. Carolina,* or perhaps to the same garden form that was described by Ehrhart in 1789 under the name *R. lucida,* to which species it was referred in Martyn's edition of Miller's *Dictionary* in 1807.

Gronovius in the second edition of the *Flora Virginica* (1762) adds a third species from Virginia, Clayton's "*Rosa alta palustris*" (his previous species being "*sylvestres*" or Wood Roses), and refers all three to Linnæus's *R. canina,* as varieties. Dr. Gray found in 1839 in Clayton's herbarium, preserved at the British Museum, two specimens, one "our *Rosa parviflora,*" and the other near to it. Clayton's tall swamp rose was probably *R. Carolina.*

In 1772 DuRoi described two roses, then in cultivation in German gardens, under the names *R. Virginiana* and *R. Carolina.* The first appears to have been the true *R. Carolina,* and the latter Ehrhart's

R. parviflora, and Willdenow so understood them twenty-four years later.

In 1785 we find the first determinations of American roses by an American botanist, in the *Arbustum Americanum* of Humphrey Marshall. He mentions and partially describes four species as found in Pennsylvania, *R. Carolinensis*, *R. palustris*, *R. humilis*, and *R. Pennsylvanica plena*. The first, or the "Wild Virginia Rose," is given in all probability simply to cover the ground already occupied, for the description, as evidently as the names, is taken wholly from Linnæus and Miller. The second species, the "Swamp Pennsylvania Rose," is the true *R. Carolina*, and his description is a better one than had before been made. The *R. humilis*, or "Dwarf Pennsylvania Rose," is without doubt what has usually been regarded as Ehrhart's *R. parviflora*, and his name has every right to recognition in preference to the latter. It is not easy to account for the double-flowered form of this, of which he makes his last species.

Wangenheim, who as a captain in the Hessian forces had been from 1777 to 1780 in this country, after his return to Germany published in 1781 a description of some North American trees and shrubs, and in 1787 a more elaborate account in his *Beytrag zur teutschen Forstwissenschaft*. In the first he describes only the *R. Carolina*, but in the latter, in addition to a good description and recognizable figure of that species, he gives descriptions of "*R. Virginiana*" and of "*R. Pennsylvanica flore pleno, mihi*," the first not recognizable, the other a myth as respects any wild native species.

Walter in his *Flora Caroliniana* (1788) mentions only *R. Carolina*, with varieties "calycibus laciniis brevibus integris; et longis, laciniatis." This is the earliest reference to the rose which Michaux afterwards described as *R. setigera*.

Aiton's *Hortus Kewensis* (1789) refers everything previously published to *R. Carolina*, under a half-dozen varieties. Here first appears *R. blanda*, with a good description, stated to be a native of Newfoundland (where it was collected by Sir Joseph Banks) and Hudson's Bay, cultivated since 1773 by James Gordon. In the same year Ehrhart published, in his *Beitrage zur Naturkunde*, three species then in cultivation in the gardens at Hannover; viz., *R. parviflora*, of which he knew only a form with double flowers, *R. corymbosa*, which he rightly considered the same as the Linnæan *R. Carolina*, and *R. lucida*. He gives *R. Carolina* of DuRoi as a synonym of *R. parviflora*, and appears to have had DuRoi's description in mind in drawing up his own. There was probably some connection between this double-flowered

species of Ehrhart and the double-flowered *R. Pennsylvanica* of Marshall and of Wangenheim. Its origin is of course uncertain, but it may have been the survival in European gardens of the *Rosa Carolina fragrans* of Dillenius, the single form having become rare through neglect. Willdenow knew it only as double; Lindley also, in 1820, had never seen it single; and the only cultivated specimen in the Gray herbarium, from Jard. Luxembourg (1814), is double. This specimen differs little otherwise from native specimens of the species for which I have adopted the earlier name of *R. humilis.* Ehrhart, however, described it as having the calyx-lobes entire, which is not the case in *R. humilis.* His *R. lucida,* as it was more fully described by Willdenow, who probably knew what Ehrhart meant, may be with some certainty identified with the common New England species with dark shining leaves, and the name may be accepted as the earliest, and as appropriate.

Willdenow in 1796, in his *Berlinische Baumzucht,* describes these three species (*R. parviflora*, *R. lucida*, and *R. Carolina*) more in detail, as again in his edition of the *Systema* in 1799, where he contrasts what he considers to be their distinctive characters, but overlooks the most important differences. In the latter work he adds Aiton's *R. blanda.*

Borkhauser in 1790, in an account of the shrubs of Hesse-Darmstadt, described a *Rosa fraxinifolia,* which Gmelin, in his *Flora Badensis* (1806), says was then common in cultivation and suspects to be the same as Aiton's *R. blanda.* There is no reason for doubting their identity.

Salisbury took occasion in his *Prodromus* (1796) to substitute arbitrarily the name *R. fragrans* for the Linnæan *R. Carolina.*

The next decided advance was made by Michaux, who in 1803, in the *Flora Boreali-Americana,* published his *R. setigera* and *R. lævigata,* — the latter an introduced species that had been in cultivation in Georgia for over twenty years. His other species, *R. Caroliniana* and *R. Pensylvanica,* are shown by his herbarium to be, the first *R. humilis,* and the second a mixture of *R. Carolina* and *R. blanda.* Willdenow in his *Enumeratio* (1809) added *R. nitida* and *R. gemella.* The first is a well-marked species that had been found by Sir Joseph Banks in Newfoundland, and had become introduced into England and upon the Continent, though Willdenow was ignorant of its origin. *R. gemella* was also a cultivated species, described as having curved infra-axillary spines, and as intermediate between *R. lucida* and *R. Carolina,* but the leaves not at all shining. This is referable, with

little doubt, to *R. Carolina*, and the specimens in Willdenow's herbarium, as found by Crepin, confirm this view, at least in part.

In the second edition of the *Hortus Kewensis* (1811), by the younger Aiton, the only change made from the first is in the addition of *R. rubifolia* (usually credited to Robert Brown, though not included in his *Works*), based upon a pubescent form of *R. setigera* that had been introduced into the gardens of England.

In 1814 Pursh published the *Flora Americæ Septentrionalis*, in which he adopts all the species (and descriptions) of Willdenow's *Systema* and *Enumeratio*, adding Michaux's *R. setigera* and Aiton's *R. rubifolia*, as also two new species, *R. Lyonii*, which is a western form apparently of *R. humilis*, and *R. suaveolens*, which is the introduced Eglantine (*R. rubiginosa*). With Aiton and Willdenow, he retains the Linnæan *R. pendulina* as American, though he states that he had never seen it indigenous. He is evidently at fault in his understanding of several of the species, his *R. nitida* and *R. gemella* being both probably *R. humilis*, and his description of *R. blanda* is so modified in the appendix as to show that *R. nitida* is meant. He also describes an introduced garden species as *R. lutescens*.

Dr. Bigelow in his *Plants of Boston* (1814) recognized but a single native species (*R. Carolina*) in the region about Boston, and in the later editions of 1824 and 1840 expressed the same opinion. He may well have been encouraged in this belief by his experience (as narrated by Amos Eaton) in sending "three specimens to the greatest botanist in Europe [Sir J. E. Smith], which were all taken from different parts of the same plant. He received an answer, making two of the specimens different described species, and the third one a new species."

In the same year Rafinesque published in the *Précis des Découvertes* two new species, *R. flexuosa* and *R. enneaphylla*. The last may be referred with sufficient confidence to *R. Carolina*, while the first is evidently the introduced *R. canina*. As the name *R. flexuosa* was preoccupied, Trattinnick afterwards proposed for this the name *R. Raffinesquejana*. In 1816 Poiret published, with descriptions, in the supplement to Lamarck's *Dictionnaire de Botanique*, two species whose names Bosc had previously proposed in the catalogues of the Paris Garden, and which were supposed to be of American origin. The *R. rubrispina* is identified with *R. nitida*. The *R. Evratina*, however, as afterward figured by Redouté, appears to be a European species. His *R. rapa*, on the other hand, which is credited by Poiret to Scotland, has been supposed to be a double-flowered form of *R. lucida*.

Donn also, at about the same time, in his Catalogue of the Cambridge Garden in England, gave some additional names to already known species; his *R. florida* being *R. Carolina*, the *R. Cherokeensis* the same as *R. lævigata*, and his *R. fenestrata* the smooth form of *R. setigera.*

Sir James E. Smith in his revision of the genus in Rees' Cyclopedia (1816) describes fifty-seven species, of which eleven are credited to America; but these include *R. gemella*, *R. Lyonii*, *R. pendulina*, and *R. lævigata*, and *R. rubifolia* as well as *R. setigera*, — thus leaving but six actual native species. Under *R. Carolina* ("common in our shrubberies") he mentions "*R. Pennsylvanica* of the gardens."

In 1817 *R. Montezumæ*, HBK., discovered by Humboldt and Bonpland in the high mountains of Mexico (but in all probability only a naturalized form of the European *R. canina*), was described by them, and also figured by Redouté in *Les Roses*. This latter work, published between 1817 and 1824, the text by Thory, included figures of *R. lucida*, *R. parviflora* (double), *R. rubifolia*, *R. Carolina*, and of several forms of the latter under the name of *R. Hudsoniana*. *R. blanda* is referred to *R. cinnamomea* as a variety. Two other publications illustrating the genus appeared early in the century, which have not been accessible to me; viz., Roessig's *Die Rosen* (1802–1820), containing figures of *R. Carolina* and "*R. Virginiana simplex*," and Andrew's *Roses* (1805–1828).

Of far more value is the *Rosarum Monographia* of Lindley (1820), in which both the grouping of the species and the descriptions are more satisfactory than anything that had preceded, and are accompanied by several figures that are in most cases excellent. He admits fourteen American species, viz. *R. nitida* (or "Dwarf Labrador Rose"), *R. rapa* ("as distinct from *R. lucida* as a species can be;" he speaks of specimens from the Southern States, probably *R. humilis*), *R. lucida* and *R. laxa*, Lindl., *R. parviflora* ("a universal favorite"), *R. Woodsii*, Lindl., *R. Carolina*, *R. blanda* and *R. fraxinifolia* (the smooth form of *R. blanda*), *R. stricta* (the same as the *R. pendulina* of Linnæus), *R. rubifolia* and *R. setigera*, without perceiving them to be the same, *R. lævigata* (believing it a native of Georgia, he tries to distinguish this from *R. Sinica*), and *R. Montezumæ*. His *R. laxa* appears, from his figure and description, to be a glaucous garden form of *R. lucida*. The *R. Woodsii*, said to be a native of the country near the Missouri, was described from a cultivated specimen. It had previously been sent to France by an English nurseryman as an American rose with black and yellow flowers, and had so been advertised

under the name of *R. lutea nigra.* It was afterward (in 1825) more correctly described by Lindley, with a good figure, in the Botanical Register (t. 976), and is readily identified with a western species otherwise unnamed. Lindley also described in the *Monographia* his *R. acicularis,* a Siberian species which is now known to occur in Alaska, and is closely allied to *R. blanda.* He states that *R. blanda* had been collected on the Northwest Coast by Menzies, who was with Vancouver upon the island which bears that navigator's name, and who there doubtless found the common species afterward named by Presl *R. Nutkana.*

In the same year with Lindley's monograph appeared that of Rafinesque, who follows Pursh, with the addition of *R. Evratina* and his own early *R. enneaphylla,* and descriptions of fifteen new species from east of the Mississippi. These it is unnecessary to enumerate, though they were taken up by Seringe, and, following him, by Don and Dietrich, and are even discussed by Crepin.

In 1823 was published James's account of Long's expedition to the Rocky Mountains, in which a description is given by Bradbury of a rose collected by Dr. Baldwin near the mouth of the Missouri River, under the name of *R. mutabilis.* Beck soon after identified this with Michaux's *R. setigera,* and correctly, as is shown by the original specimen preserved in the Torrey herbarium.

In 1823 also appeared Trattinnick's *Rosaceæ,* with a detailed account of the Roses, based, however, solely upon the descriptions and figures of previous publications. He found occasion to substitute *R. Solandri* for *R. fraxinifolia* as understood by Lindley, *R. Raffinesquejana* for Rafinesque's *R. flexuosa,* and *R. Sprengeliana* for a form of *R. Carolina* in German gardens, which Sprengel had named *R. Virginica;* but otherwise admits nearly every American species that had come to his knowledge, — twenty-four in all. The revisions in 1825 by Sprengel in the sixteenth edition of the *Systema Vegetabilium,* the less complete one of Loiseleur in the *Nouveau Duhamel,* and even that of Seringe in De Candolle's *Prodromus,* are of little more critical value. Sprengel follows Lindley, substituting *R. Lindleyi* for *R. laxa* (as a preoccupied name); Loiseleur refers Michaux's *R. Pennsylvanica* to the European *R. majalis,* as a variety, and his *R. setigera* to *R. arvensis;* Seringe follows Sprengel, but drops *R. gemella,* refers *R. pendulina* to *R. alpina* as an American variety, and places *R. blanda* under *R. fraxinifolia,* which he confines to the Northwest Coast. He also substitutes *R. Rafinesquii* for *R. nivea,* one of Rafinesque's new species, all of which are given by him.

American botanists up to this time had accepted Pursh as their authority, and the lists (in 1818) of Muhlenberg in his *Catalogue*, and of Nuttall in his *Genera*, as well as the species adopted by Amos Eaton in his *Manual* of the same year, are taken from him with little change. Muhlenberg, however, knew actually of but two native species in Pennsylvania, though he failed to identify them correctly, as appears from the manuscript of his unpublished *Flora*, now in the library of the Gray herbarium, in which he describes "*R. Caroliniana*" and "*R. corymbosa*," the first evidently being *R. humilis* and the last *R. Carolina*. Barton also, in his *Compendium* (1818), as afterward Darlington in his *Florula Cestrica* (1826) and *Flora Cestrica* (1837), recognized only the same two species, understanding them rightly. Elliott, in the *Botany of South Carolina and Georgia* (1821), describes from personal knowledge only two native species, "*R. parviflora*" and "*R. lucida*" (i. e., *R. humilis* and *R. Carolina*), with the introduced *R. lævigata* and *R. suaveolens* (*R. rubiginosa*), to which he adds Michaux's *R. setigera*, and *R. gemella*, *R. Carolina*, and *R. lutescens*, taking the descriptions from Pursh and Smith. Torrey, in his *Flora of the Northern and Middle States* (1824), and in the *Compendium* (1826), gives as native species *R. parviflora*, *R. nitida*, *R. lucida*, *R. gemella*, and *R. Carolina*, the descriptions taken from Willdenow. *R. nitida* and *R. gemella* he had never seen, but the other species he describes in the *Flora* more in detail, and with his usual accuracy.

In 1823 an expedition to the Red River of the North was sent out by the Secretary of War (J. C. Calhoun), under Major Long, who reached Lake Winnipeg and returned by the northern shore of Lake Superior. In Keating's account of the expedition (1825), Schweinitz gave a list of the plants collected, and among them described *R. Sayi* as a new species. This has been considered a form of *R. blanda*, or of *R. acicularis*, but it is, in my opinion, distinct. In 1827 Chamisso and Schlechtendal published in *Linnæa* the first described species from the Pacific Coast (*R. Californica*), which had been collected in 1816 near San Francisco by Chamisso while attached to the Russian expedition under Kotzebue.

The first discussion of the roses found outside of the Atlantic States was by Borrer, an English botanist, in Hooker's *Flora Boreali-Americana*, in 1831, and included all the species that had been collected in British America by Banks, Richardson, Drummond, Douglas, Menzies, Scouler, and others. He evidently found difficulty in determining the species satisfactorily, and the specimens of the same col-

lectors that are in our herbariums show in most cases how far it was done successfully. Of his *R. nitida*, *R. lucida*, *R. Woodsii*, *R. Carolina*, and *R. blanda* in part, there can be no doubt. Some specimens that I would now place under *R. Sayi* are referred to *R. blanda*, and others to *R. stricta*, var. The species of the Northwest Coast (*R. Nutkana*) is referred in part to *R. fraxinifolia*, following Seringe in the *Prodromus*, and in part to *R. cinnamomea*. Some specimens of *R. Woodsii* are referred to *R. majalis;* and it is probable that the specimens from Lake Huron named *R. lævigata?* were *R. setigera*.

The next revision of any moment is that by Torrey & Gray, in the *Flora of North America* (1840). Here *R. setigera* is for the first time identified with *R. rubifolia*, and *R. Carolina*, *R. nitida*, and *R. blanda* (mainly) are clearly defined, while *R. lucida* is made to include all other forms of the Atlantic States. *R. Woodsii* and *R. Californica* are adopted with no other knowledge of them than that derived from the original descriptions; while *R. cinnamomea*, *R. fraxinifolia*, and *R. stricta* are taken from Borrer, with little variation, for the then little known western and northern forms. In addition, two remarkably distinct species of Nuttall's are for the first time described; viz., *R. foliolosa*, from Arkansas and Texas, and *R. gymnocarpa*, from Oregon. No reference is made to Schweinitz's *R. Sayi*, which is first noticed by Eaton & Wright, in the eighth edition of Eaton's *Manual* (1840), who otherwise follow Borrer, adding *R. parviflora*, *R. gemella*, and *R. rubifolia*.

R. Maximiliani, collected by Prince Maximilian von Wied in a journey to the Upper Missouri, and published by Nees von Esenbeck in 1841, is the same as Lindley's *R. Woodsii*, as is evident from Nees's careful description.

Torrey, in 1843, in the *Flora of New York*, described the three species of that State as *R. Carolina*, *R. lucida*, and *R. blanda*, his *R. lucida* being the common *R. humilis*, from which he failed to distinguish such specimens of the rarer *R. lucida* as he may have seen. In New England, where *R. lucida* is frequent, the difficulty in uniting the species was greater, and we accordingly find Emerson in the *Woody Plants of Massachusetts* (1846) recognizing *R. lucida* (the "early Wild Rose," *R. humilis*), *R. Carolina* (the "Swamp Rose"), and *R. nitida* (the "Shining Rose"), the last including the real *R. lucida*. Wood in his *Class-Book* (1846, and later editions) includes *R. lucida* under *R. Carolina*, his *R. lucida* also being *R. humilis*. Finally, Dr. Gray, who in the first edition of his *Manual* (1848) had retained *R. nitida* as distinct, in the second (1856) and later editions

refers all three forms (*R. lucida, humilis*, and *nitida*) to one species, *R. lucida.* So also in the Southern States, the "Dwarf Rose" of dry soils and woods, which A. M. Curtis had correctly known in 1834 as *R. parviflora*, was called *R. lucida* by him in his *Shrubs of N. Carolina* (1860), and by Chapman in the *Flora of the Southern States*, of the same year.

The most thorough treatise upon any portion of the genus that had yet appeared was that of C. A. Meyer, *Ueber die Zimmtrosen*, in 1847. He discusses the comparative value of different characters, and is the first to distinguish the *Carolina* group of species ("*Rosæ operculatæ*") as distinct from *R. blanda* and its allies. His determinations, however, are of less value respecting our species from the want of material and his consequent dependence upon the work of others. The species placed by him in his section of Cinnamon Roses are *R. blanda, stricta, Woodsii*, and *Californica.*

In 1849 Presl described in the *Epimeliæ* under the name of *R. Nutkana*, and from specimens that had been collected by Haenke on Vancouver Island early in the century, the same species that had been collected previously by Menzies and by various collectors afterwards, and which had been referred both to *R. fraxinifolia* and to *R. cinnamomea.* Presl's name was long overlooked, until brought forward by Crepin.

At about this time began the long series of collections that have been made in our western territories, mainly in connection with government expeditions and surveys. The determination of the roses of these collections was attended with the usual difficulties. While Nuttall's *R. foliolosa* and *R. gymnocarpa* were easily recognized, the general reference of all the other forms of the interior and of California was to *R. blanda.* In the Botany of Whipple's Report, Dr. Torrey refers to that species not only *R. fraxinifolia* (i. e., *R. Nutkana*), but *R. Californica* and *R. Woodsii.* Three species at the most were at any time recognized, — the large-flowered northern *R. fraxinifolia*, the *R. Californica* of the coast, and *R. blanda*, which included all the rest. In 1872 Dr. Gray gave the name *R. pisocarpa* to a rose collected by Hall on the Lower Columbia, and in 1874 Porter in the *Flora of Colorado* separated, under the name of *R. Arkansana*, a common form of the Rocky Mountain region that had been collected long before and often, from Texas to British America.

The most important publication of all upon American roses has been in the *Primitiæ Monographiæ Rosarum* of Crepin, during 1875 and 1876, — a general work upon which he is still patiently laboring.

Considering the limited amount of material at his command, his work is excellent, though as yet in a measure tentative and provisional, and with a tendency to multiply species. He has examined critically all the specimens of Willdenow's original herbarium, and has clearly defined the characters by which the early species are to be distinguished, and he was the first to perceive and indicate the limited range of *R. lucida*. His disposal of the northern and western species may be thought less satisfactory. He places under *R. blanda* all the pubescent and acicular and even the spiny western forms which correspond to Lindley's *R. Woodsii* and to the *R. Arkansana* of Porter, while the resinous-pubescent and acicular form he prefers to consider a variety of *R. acicularis*, though at first thought distinct and named *R. Bourgeauiana*. He revives Presl's *R. Nutkana*, but would separate two of its forms under the names *R. Aleutensis* and *R. Durandii*, the latter based upon some peculiar specimens of Hall's collection that had been referred by Dr. Gray to *R. Kamtschatica*. Finally, upon a specimen collected by Fendler in New Mexico he proposes, with some doubt, a new species as *R. Fendleri*. His general arrangement of our species is under the following sections: —

1. Synstylæ. — *R. setigera.*
2. Alpinæ. — *R. acicularis* and *blanda.*
3. Cinnamomeæ. — *R. Nutkana, Durandii, Aleutensis, Californica,* and *Fendleri?*
4. Carolinæ. — *R. Carolina, lucida, nitida, parviflora,* and *foliolosa.*
5. Gymnocarpæ. — *R. gymnocarpa.*

A still later revision is that of Regel of St. Petersburg, in his *Tentamen Rosarum Monographiæ* (1877). He retains *R. blanda*, *R. Carolina*, *R. lucida*, *R. nitida*, and *R. Woodsii*. To *R. Woodsii* he refers *R. Nutkana*, *R. Lyonii* of Pursh, and some Asiatic forms; and to *R. Carolina* the *R. Californica* of Cham. & Schlecht., proposing another *R. Californica*, Regel, on specimens collected near San Francisco by Tiling. He refers to *R. acicularis*, var. *Gmelini*, Crepin's var. *Bourgeauiana; R. gymnocarpa* to *R. pimpinellifolia; R. fraxinifolia* to *R. cinnamomea; R. setigera* to *R. moschata*, but *R. rubifolia* to *R. repens;* and *R. Montezumæ* to *R. canina.*

In 1880 *R. minutifolia*, a very peculiar species from Lower California, was described by Engelmann in Coulter's Gazette, and *R. spithamæa* by myself in the Botany of California, the latter probably only an extreme form of *R. Californica.* And last of all, in 1881, Palmer

found in the mountains of Coahuila, Mexico, a rose that was described the next year in my list of his collection under the name of *R. Mexicana.*

The material at hand in the preparation of the following revision, while none too ample for correct results, has been enough at least to furnish all that was desired of dubious and difficult forms. The collections that have been examined, besides those of the Gray Herbarium, have included the large accumulations of Dr. Engelmann, those of the Torrey Herbarium, of the Philadelphia Academy of Sciences, of the Department of Agriculture at Washington, and of the Arnold Arboretum, besides the private collections of J. H. Redfield, of Philadelphia, H. G. Jesup, of Hanover, N. H., and J. Donnel Smith, of Baltimore, and contributions from Dr. A. Gattinger of Nashville, Dr. C. Mohr of Mobile, Howard Shriver, of Wytheville, Virginia, and Warren Upham of Minneapolis.

Classification, Synopsis, and Descriptions of Species. — The differences which have to be taken into consideration in determining the species of the genus *Rosa* are so variable, and present such a multitude of combinations, that there are few genera which illustrate more fully the different views that can be taken by different botanists respecting the specific value of the same characters. The number of species admitted by Linnæus in 1762 was fourteen; by Sir J. E. Smith in 1816, fifty-seven; by Lindley in 1820, seventy-eight; by Seringe in 1825, ninety-one, besides fifty-one which he classed as imperfectly known. Bentham & Hooker, in the *Genera Plantarum* (1865), limit the number of species then known to thirty. The number of species credited to Great Britain by Lindley was ten; by Baker (1871), eleven; by Hooker (1871), seven, with six subspecies; and by Bentham, in the same year, five "probably real species." Déséglise in 1876 makes the whole number of Old World species 410, of which 323 are European (66 in Great Britain), 75 Asiatic, and four African, — eight being of uncertain habitat. Crepin's revision of the European species (1869) accords in the main, at least provisionally, as respects the weight and number of species, with Déséglise. Nyman in the *Conspectus Floræ Europeæ* (1878) enumerates forty European species, with fifty-two subspecies. Regel in his *Tentamen* (1878) recognizes a total of fifty-six species, of which seventeen occur in Europe, thirty-four are Asiatic, and five American, several of our species being referred to foreign types, as we have seen. On the other hand, Gandoger (*Tabulæ Rhodologiæ Europæo-Orientales,* 1881) distributes the Old World forms into twelve genera and 4,266 species.

A perfect agreement of opinion respecting the roses of America is therefore not to be expected. In the following revision eighteen species are recognized. Some of these are very clearly defined, while others are more nearly related and are united more or less closely by intermediate forms, or diverge into extremes in one or more directions. There has seemed to be no necessity for proposing a single new species, though it would have been easy to increase the number largely. But if farther subdivision were attempted, it would be difficult to say where it should stop.

In the general grouping I have followed nearly that of Crepin. The species divide naturally into two series, one having the sepals persistent or breaking away at length by an irregular rupture above the base, in the other the sepals deciduous from the receptacle by a clean circumscission at the base. The first divides again into two groups, the one without and the other with infrastipular spines. The unarmed group ranges from extreme Northern Alaska to Hudson's Bay, Newfoundland, and the northern border of the Atlantic States, and southward along the Rocky Mountains to Colorado, as also westward through Northern Asia and Europe to Scandinavia. This may be considered all one species (*R. blanda*), or it can be divided into four fairly well-defined species, which may well be believed to be derivatives from one common stock. The second group ranges from Alaska along the coast to Lower California, and through the interior to Western Texas and the plains east of the Rocky Mountains. The extreme northwestern and southwestern forms (*R. Nutkana* and *R. minutifolia*) are well defined, the latter remarkably so. The four remaining species are closely related and run into each other more or less, the most eastern one showing in its lobed sepals a gradation toward the Atlantic *Carolina* group.

The second series, with deciduous sepals, has two strongly characterized outlying members, the eastern climbing species with connate styles (*R. setigera*), and the western *R. gymnocarpa*, with its receptacle becoming perfectly naked and closed in fruit. Two other related but apparently distinct species occur in the extreme Southwest and in adjacent Mexico; but the four remaining species, occupying the region east of the Mississippi, are again very close allies.

The extreme of possible reduction would seem therefore to be to nine species, viz.: —

1. R. blanda. (*R. acicularis*, *R. Sayi*, *R. Arkansana.*)
2. R. Nutkana.
3. R. Woodsii. (*R. Californica*, *R. Fendleri*, *R. pisocarpa.*)

4. R. minutifolia.
5. R. Carolina.
6. R. humilis. (*R. lucida, R. nitida.*)
7. R. foliolosa. (*R. Mexicana.*)
8. R. setigera.
9. R. gymnocarpa.

A synopsis of the grouping and differentiation of the species, as here adopted, may be made as follows, exceptions being disregarded: —

Synopsis of Species.

I. — Sepals connivent and persistent after flowering.

A. — Without infrastipular spines; acicular prickles often present. Pedicels and receptacles naked.

* Fruit oblong. Arctic.

1. R. aciculаris. Stipules dilated; leaflets usually 5, obtuse or cordate at base, not resinous: flowers solitary; sepals entire, not hispid. — Northern Alaska.

* * Fruit globose. More southern.

2. R. blanda. Prickles usually few or none: stipules dilated; leaflets 5 or 7, cuneate at base and petiolulate, simply toothed, not resinous; flowers corymbose or solitary; sepals hispid, entire. — Newfoundland to Lake Superior.

3. R. Sayi. Very prickly: stipules dilated; leaflets 5 or 7, sessile and obtuse or subcordate at base, resinous and doubly toothed: flowers solitary; outer sepals laterally lobed, not hispid. — Colorado to British America and Lake Superior.

4. R. Arkansana. Very prickly: stipules narrow; leaflets 7 to 11, subcuneate at base, simply toothed, not resinous: flowers corymbose; sepals not hispid, the outer lobed. — Western Texas to British America.

B. — Infrastipular spines present, often with scattered prickles.

* Pedicels and receptacles naked. Leaflets 5 or 7.

+ Sepals entire.

++ Flowers and fruit large, solitary. Stipules dilated.

5. R. Nutkana. Spines stout, straight or recurved: leaflets rounded at base: fruit globose. — Alaska to Oregon and Idaho.

++ ++ Flowers and fruit corymbose or solitary, smaller. Stipules short and narrow.

6. R. pisocarpa. Spines straight, slender, ascending or spreading: leaflets rounded or subcuneate at base: fruit globose, small. — Oregon and Washington Territory.

7. R. Californica. Spines stout, straight or recurved: leaflets obtuse at both ends, often villous, as also the pedicel and receptacle: fruit ovate, with a prominent neck. — Oregon to Lower California.

8. R. Fendleri. Spines straight or recurved: leaflets cuneate at base, not villous: fruit globose. — From the Sierra Nevada and Cascades to the Rocky Mountains.

+- +- Outer sepals laterally lobed.

9. R. WOODSII. Spines slender, straight or recurved: stipules short: flowers corymbose or solitary, on very short pedicels: fruit globose. — Colorado to British America and the Mississippi.

* * Receptacle densely prickly. Sepals pinnatifid.

10. R. MINUTIFOLIA. Very spiny and prickly: stipules short, narrow; leaflets very small: flowers small, solitary, on very short pedicels: fruit globose. — Lower California.

II. — Sepals spreading after flowering and deciduous. Infrastipular spines present, often with scattered prickles.

A. — Styles distinct, numerous, persistent. Base of the calyx persistent on the globose fruit. Calyx, receptacle, and pedicel hispid. Teeth simple and pubescence not resinous, except in *R. Mexicana*.

* Pedicels usually elongated, and leaflets seven. Eastern species.

+- Leaflets finely many-toothed.

11. R. CAROLINA. Tall, with stout straight or recurved spines: stipules narrow; leaves dull green: flowers corymbose or solitary; outer sepals occasionally lobed. — Nova Scotia to Florida and the Mississippi.

+- +- Leaflets coarsely toothed.

12. R. LUCIDA. Often tall, with stout straight or recurved spines: stipules dilated; leaflets smooth and shining above: flowers corymbose or solitary; outer sepals frequently lobed. — Newfoundland to New York.

13. R. HUMILIS. Low, with straight slender spines: stipules narrow: flowers corymbose or solitary; outer sepals always lobed. — From the Atlantic coast to the Mississippi.

14. R. NITIDA. Low, with straight slender spines and very prickly: stipules dilated; leaflets glabrous: flowers mostly solitary; sepals entire. — Newfoundland to New England.

* * Pedicels very short: leaflets and stipules narrow: flowers solitary; outer sepals lobed.

15. R. FOLIOLOSA. Spines short, straight or curved: leaflets 7 to 11, glabrous or nearly so. — Indian Territory to Texas.

16. R. MEXICANA. Spines stout, straight: leaflets 5 to 7, resinous beneath and doubly toothed. — Coahuila, Mexico.

B. — Styles connate into a smooth slender column, persistent. Sepals short; base of the calyx persistent.

17. R. SETIGERA. Climbing, with stout recurved spines and no prickles: stipules very narrow; leaflets 3 or 5: flowers corymbose: fruit oblong to globose. — Ontario to the Gulf of Mexico.

C. — Styles few, distinct, the summits with the calyx deciduous from the very contracted top of the smooth receptacle. Sepals short.

18. R. GYMNOCARPA. Spines straight, slender: stipules narrow; leaflets doubly serrate: flowers small, solitary or few. — British Columbia to Western Montana and California.

I. — Sepals connivent after flowering and persistent upon the receptacle.

A. — Stems without infrastipular spines, naked or more or less covered with slender prickles. Pedicel and receptacle naked.

* Fruit oblong. Arctic species.

1. R. ACICULARIS, Lindl. Stems low, often densely prickly: stipules very broadly dilated, or narrow, glandular-ciliate; leaflets 3 to 7 (usually 5), broadly elliptical and obtuse or acutish, to narrowly oblong and acuminate, more commonly oblong-lanceolate, mostly obtuse or slightly cordate at base and subsessile, coarsely simply or occasionally somewhat doubly serrate, often entire below the middle, glabrous above, paler and more or less tomentose beneath, the terminal 1 or 2 inches long; rhachis glabrous or pubescent, unarmed: flowers solitary; sepals nearly glabrous, not hispid, entire: fruit 6 lines long, contracted above into a neck. — Ros. Monogr. 44, t. 8. *R. Carelica*, Fries; Fl. Dan. Suppl. t. 75.

HAB. Northern Alaska; also through Siberia and in Northern Europe. — At Fort Yukon (*Ketchum*); Fort Simpson (*Onion, Kennicutt & Hardisty*); Kuskokoin Valley (*Weinmann*); St. Michel's Island (*Turner*); and on the Kowak River (*McLenegan*).

Only flowering specimens of this species have been seen from Arctic America, but these accord closely with the figures and with Lindley's and Meyer's descriptions, and with some of the Old World specimens that are so named in Herb. Gray. The young receptacle varies somewhat in form, but is usually distinctly elongated. The flowers are 1½ to 2 inches broad, deep rose-color and fragrant; they are said to be sometimes two or three together. The leaves vary much in form, but incline to a rather peculiar oblong shape, most strongly serrate toward the summit. The sepals are described as sometimes hispid in Asiatic specimens, or with a narrow lateral lobe, and the leaf-stalk as sometimes prickly.

* * Fruit usually globose. More southern species.

2. R. BLANDA, Ait. Stems 1 to 3 feet high, wholly unarmed, or with usually a few slender straight scattered prickles, sometimes more densely prickly: stipules dilated, naked and entire, or slightly glandular-toothed above; leaflets 5 to 7 (very rarely 9), usually oblong-oblanceolate, mostly cuneate at base and shortly petiolulate, coarsely simply toothed, glabrous above, paler and glabrous or more or less pubescent beneath, not resinous or very rarely slightly so, usually large (the terminal ¾ to 2½ inches long); rhachis pubescent, sometimes sparingly prickly: flowers large, corymbose or often solitary; sepals entire, shortly hispid or sometimes naked: fruit globose with more or less of a neck below the calyx, sometimes oblong-obovate by a more gradual attenuation of the base, 4 to 6 lines long. — Hort. Kew. 2. 202; Jacq. Fragm. t. 105. *R. fraxinifolia*, Gmelin; Lindl. Bot. Reg. t. 458. *R. Solandri*, Tratt. Ros. 2. 150.

HAB. On rocks, and rocky shores of rivers and lakes, from Newfoundland and Hudson's Bay to Northern New York, Illinois, and Wisconsin, and to Lake Winnipeg. — Quebec (*Mrs. Percival*); Vermont, banks of Winooski River and Lake Champlain (*Pringle*); New York, Hudson River near Troy (*Jesup*), Watertown (*Gray*); Michigan (*Houghton*), at Mackinaw Island (*Dr. Wright, Drake*); Canada (*Richardson*); Ontario, and at Thunder Bay (*Macoun*); Illinois, at Fountaindale (*Bebb*), La Salle (*Engelmann*), and Waukegan (*Sargent*); Wisconsin (*Douglass, Hale, Lapham*), White Fish Bay (*Gillman*), and Ashland (*Engelmann*); Minnesota, at Duluth (*Engelmann*), with the sepals both densely hispid and nearly smooth; Manitoba, at Fort Garry (*Bourgeau*). Originally reported as found by Sir Joseph Banks about Hudson's Bay and in Newfoundland. Macoun also reports it from Harbor Grace, Newfoundland, and on Pictou and Magdalen Islands.

Flowers pale rose-color, two inches broad. The typical smooth and slightly prickly form is the more common eastward. The more tomentose form, which was considered the typical form by Lindley, and named *R. Solandri* by Trattinnick, is the var. *pubescens* of Crepin. Of the state with more abundant prickles he makes the var. *setigera*, though including also under it what is here separated as *R. Arkansana*. Both of these forms are more frequent westward, where also the sepals are sometimes naked.

3. R. SAYI, Schwein. Stems usually low (1 or 2 feet high), thickly covered with prickles: stipules usually dilated, glandular-ciliate and resinous; leaflets 3 to 7 (usually 5 or 7), glabrous or slightly pubescent above, more or less resinous beneath, broadly elliptical to oblong-lanceolate, usually sessile and rounded or subcordate at base, more or less doubly and glandular-toothed, the terminal ¾ to 2 inches long: flowers solitary (very rarely 2 or 3); outer sepals with one or more very narrow lateral lobes (very rarely all entire), not hispid or slightly so on the margin: fruit as in the last. — Keating, Long's Exped. Appx. 113. *R. acicularis*, var. *Bourgeauiana*, Crepin, Prim. Monogr. Ros. in Bull. Soc. Bot. Belg. 15. 390.

HAB. Frequent in the Rocky Mountains from Colorado to British America, and on Lake Superior and northward. — Colorado (*Parry, Hall & Harbour*), on Clear Creek and Douglas Mountain above Empire (8,500 to 10,500 feet altitude), at Twin Lakes, and in Berthoud's Pass (*Engelmann*), Sangre de Cristo Pass (*Hooker & Gray*), Mosquito Pass and Twin Lakes (*Wolf, Coulter*), Idaho Springs (*Greene*), Manitou Springs (*Engelmann & Sargent*), Breckenridge (*Brandegee*), on the Upper Platte (*Fremont*); British America, at the base of the Rocky Mountains (*Drummond, Bourgeau*), on the Mackenzie River, and at Cumberland House Fort on the Saskatchewan (*Richardson*); Ontario, at Nipigon (*Macoun*), and Silver Islet in Lake Superior (*Gillman*); Wisconsin (*Hale*), south shore of Lake Superior (*Whitney, Loring*), and White Fish Bay (*Gillman*); Northern Michigan, Eagle River (*Gillman*). The locality is not given for the original specimens of *R. Sayi*, which are now in the Schweinitz herbarium in the possession of the Philadelphia Academy. The route of Long's Expedition followed the Red River to Lake Winnipeg, and thence passed through the Lake of the Woods and along the northern shore of Lake Superior.

The flowers are large (2 to $2\frac{1}{2}$ inches broad), and fragrant. The species commemorates the naturalist, Thomas Say, the collector of Long's party.

4. R. Arkansana, Porter. Stems usually low ($\frac{1}{2}$ to 6 feet high), more or less densely prickly: foliage more or less glaucous, the stipules usually narrow, more or less glandular-toothed above and sometimes glandular-ciliate; leaflets 3 to 5 pairs (usually 7 or 9), broadly elliptical to oblong-oblanceolate, somewhat cuneate at base, nearly sessile or often petiolulate, glabrous, or more or less pubescent beneath, simply and coarsely toothed, or the pubescence sometimes resinous and the teeth rarely serrulate, the terminal $\frac{1}{2}$ to 2 inches long: flowers corymbose, very rarely solitary; sepals naked or sometimes more or less hispid, the outer with one or more lateral lobes: fruit as in the preceding. — Porter & Coulter, Syn. Fl. Colorado, 38. *R. blanda*, var. *setigera*, Crepin, l. c. 394, mainly.

Hab. Very frequent in the mountains from Western Texas and New Mexico to British America, and eastward to the Upper Mississippi and Saskatchewan. — Western Texas, on the Limpio (*Wright, igelow*); New Mexico, at Sante Fe (*Fendler, Engelmann*), and Las Vegas (*Engelmann, G. R. Vasey*); Colorado, on the Arkansas at Cañon City (*Brandegee*), at Hot Sulphur Springs, Manitou Springs, and Empire (*Engelmann*), Colorado Springs (*Torrey, Redfield*), Twin Lakes (*Wolf*), Sangre de Cristo Pass (*Hooker & Gray*), and at Denver (*Engelmann, Jones*); Nebraska, on Loup Fork (*Hayden*); Montana (*Ward*), on Frenchman's Creek (*Coues*), Upper Yellowstone (*Allen*), Nevada Creek (*Sargent*), and Hound Creek (*Scribner*); Dakota, at Devil's Lake (*Nicollet*), Fort Clark (*Stevens*), Bismarck (*Sargent*), and Pembina (*Havard*), a form very near *R. blanda;* Western Missouri, Cass County (*Broadhead*); Iowa (*Arthur, Coulter*); Minnesota, at St. Paul (*Lesquereux*), near Minneapolis (*Miss Butler, Engelmann, Upham*), Pipe Stone City (*Mrs. Bennett*), and Wabasha (*Gibson*); Manitoba, at Brandon (*Scott*); Assiniboine, Souris Plain (*Macoun*); Saskatchewan (*Bourgeau*).

The most pubescent form of this species is common upon dry prairies from the Upper Mississippi westward and to the Saskatchewan. The flowers are here sometimes white. In Eastern Minnesota and Iowa it occurs with the receptacle more or less hispid.

B. — Stems with infrastipular spines, and often more or less covered with scattered prickles.

* Pedicels and receptacles naked (very rarely hispid).

+ Sepals entire.

++ Flowers large, solitary. Fruit large. Stipules usually dilated.

5. R. Nutkana, Presl. Stems stout, 1 to 4 feet high, armed with stout straight or recurved spines, the branches sometimes unarmed, and young shoots sometimes prickly: stipules glandular-ciliate; leaflets 5 or 7 (very rarely 9), broadly elliptical to ovate or oblong or lanceolate, usually rounded at base, obtuse or acute (the terminal $\frac{1}{2}$ to 2 inches long), resinous beneath (as well as the rhachis and stipules) and the

teeth more or less glandular-serrulate, smoother above, sometimes nearly or quite glabrous (and teeth entire), or the pubescence not resinous; rhachis more or less prickly or hispid: flowers 2 or 3 inches broad, solitary (rarely 2 or 3); pedicel and receptacle very rarely hispid; sepals naked or very rarely hispid: fruit globose, not contracted above into a neck, 6 lines broad. — Epimel. Bot. 203. *R. Aleutensis*, Crepin, l. c. 14. 41. *R. Durandii*, Crepin, Bull. Soc. Bot. France (Compt. Rend.), 22. 19.

HAB. Alaska, along the coast from lat. 62° to Oregon, and in the mountains eastward to Idaho and Northern Utah. — Alaska (*Harrington, Turner, Fischer, Kellogg, Meehan,* etc.); British Columbia, on Vancouver Island (*Lyall, Engelmann*), Observatory Inlet (*Scouler*), on Fraser River (*Engelmann*), Columbia Valley (*Dawson*); Washington Territory, on Puget Sound and at Cape Disappointment (*Engelmann & Sargent*), Cowlitz (*Engelmann*), Klickitat County (*Suksdorf*), on the Wenatchee (*Brandegee*), and Fort Colville (*Wilkes, Watson*); Oregon, at Astoria and the Dalles (*Nuttall, Hall, Engelmann, Howell*), Hood River (*Mrs. Barrett, Henderson*), Blue Mountains (*Nevius, Cusick*); Idaho, on the Clearwater (*Wilkes, Spalding*), near Boise City (*Wilcox*); Northern Utah, in the Wahsatch (*Watson*).

A very variable species, though there seems to be no combination of characters upon which it can be satisfactorily divided. The species was originally made upon the nearly glabrous form (including Crepin's varieties *glabra* and *pubescens*), which is of frequent occurrence on the coast, but is the more usual one in the interior. The resinous pubescence is sometimes very dense, and, as in other species, is usually accompanied with serrulate teeth. It is very seldom that either pedicels or sepals, and still more so that the receptacles, are at all hispid. The spines are often very broad at base (on vigorous shoots sometimes a half-inch broad and long). Scattered prickles in addition to the spines are rare. *R. Aleutensis*, Crepin, was based upon a vigorous stem without spines. *R. Durandii*, Crepin, is an extreme form, with very large spines and densely hispid and prickly, and with the foliage very resinous.

A probable form with the fruit and pedicels hispid is found in Western Montana, at Rock Creek in Bitter-Root Valley (*Watson*), unarmed, and at Bozeman (*Koch*), with slender spines.

++ ++ Flowers corymbose or solitary, smaller. Fruit smaller. Stipules short and narrow.

6. R. PISOCARPA, Gray. Stems slender, armed with straight stout or slender ascending or spreading spines, or sometimes naked, not prickly: stipules mostly narrow, very rarely slightly glandular on the margin; rhachis pubescent, sometimes prickly; leaflets 5 or 7, oblong to oblong-ovate or -obovate, shortly acuminate to obtuse, rounded or subcuneate at base and sessile or nearly so, smooth above, paler and pubescent beneath, simply toothed, usually small (the terminal 5 to 18 lines long): flowers corymbose, or often solitary on short branches, an inch broad, on short slender smooth or rarely sparingly hispid pedicels;

sepals hispid or sometimes naked: fruit globose, with a very short neck, 4 or 5 lines long. — Proc. Amer. Acad. 8. 382.

HAB. Woods and stream-banks in Western Oregon and northward to British Columbia. — Oregon, Multnomah County (*Hall, Engelmann, Howell, Henderson*); Washington Territory, Klickitat County (*Suksdorf*), Seattle (*Engelmann, Sargent*); British Columbia, Vancouver Island (*Kellogg*).

Rather doubtfully distinguished from forms of *R. Californica* by the somewhat smaller and more globose fruit, and by the spines never recurved but very frequently ascending. Specimens from Thompson River in British Columbia (*Macoun*) may belong here, but are resinous. Wholly or nearly glabrous specimens also, from the Scott Mountains, California (*Greene*), and from Siskiyou County (*Pringle*), can hardly be separated from it, and another collected by the Wilkes Expedition ("Cascade Mountains to the Columbia") would be referred to it but for the somewhat recurved spines.

7. R. CALIFORNICA, Cham. & Schlecht. Stems often tall (1 to 8 feet high), with usually stout more or less recurved or sometimes straight spines, frequently scattered, or wanting, often prickly: stipules mostly narrow, usually naked, sometimes glandular-ciliate; rhachis pubescent or prickly; leaflets 3 to 7 (very rarely 9), round or broadly elliptical to oblong-ovate or -obovate, most frequently obtuse at both ends and sessile, slightly pubescent or glabrous above, villous or tomentose beneath, and simply toothed, or often more or less resinous and the teeth either entire or serrulate, very rarely wholly glabrous, the terminal $\frac{1}{2}$ to $1\frac{1}{2}$ inches long: flowers corymbose or sometimes solitary (1 to $1\frac{1}{4}$ inches broad), on slender usually short and naked (or villous or sometimes hispid) pedicels; sepals and receptacle glabrous or villous or rarely hispid (the receptacle very rarely so): fruit ovate-globose, with a usually prominent neck, about 6 lines long by 4 broad. — Linnæa, 2. 35.

HAB. Along streams throughout California, in the valleys and Coast Ranges, and in the Sierra Nevada to an altitude of 5–6,000 feet, in Western Nevada, and northward to the Columbia, and probably to British Columbia. — Lower California, near the boundary (*Orcutt*); California, from numerous localities and collectors (*Coulter, Hartweg, Pickering, Wislizenus, Bridges, Bigelow, Parry, Heermann, Dennison, Shelton, Torrey, Brewer, Bolander, Kellogg, Palmer, Hooker & Gray, G. R. Vasey, Rothrock, Congdon, Parish, Engelmann, Sargent, Cleveland, Muir, Redfield, Greene*, etc.); Western Nevada (*H. Engelmann, Watson*, n. 349 in small part, *Wheeler*); Oregon, near Portland (*Engelmann*); Washington Territory (*G. R. Vasey*), Klickitat County (*Suksdorf*); British Columbia, on Thompson River (*Macoun ?*).

An exceedingly variable species, in every respect, but it seems impossible to divide it to any good purpose. The villous-pubescent form (var. *Chamissoniana*, Meyer; var. *pubescens*, Crepin) is the typical one, while the one with resinous pubescence and serrulate teeth (var. *Petersiana*, Cham.; var. *glandulosa*, Crepin) is as widely distributed and rather more frequent. The wholly glabrous form

is very rare and found only in the San Bernardino Mountains (*Parish Brothers*), apparently with the ordinary pubescent form. In Northern California and northward it may readily be confounded, when only in flower, with *R. Fendleri* or *R. pisocarpa*. Specimens with a rather peculiar habit and wholly unarmed have been collected in Siskiyou County (*Pringle*). Suksdorf describes it as in his locality nearly thornless, sometimes ten or twelve feet high and two inches thick at base. *R. Californica*, Regel, does not differ from the common pubescent form of the original species.

R. spithamæa, Watson (Bot. Calif. 2. 444), may be a very extreme dwarf form of the resinous variety, with straight spreading slender spines, the pedicels, receptacles, and sepals densely glandular-prickly, and the leaflets mostly distinctly petiolulate. The fruit has not been collected. It has been found at New Almaden (*Torrey*), near San Luis Obispo (467 *Brewer*), and in Trinity County (*Rattan*). Mr. Rattan speaks of it as " very abundant all the way down the Trinity River from Hyenpom on the South Fork to Hoopa Valley. On the ridge between Burnt Ranch and the Forks of the Trinity it fairly covers the ground under open forests of *Quercus Kelloggii*. There I saw no specimens exceeding eight inches in height. Three to four inches was the common height. The largest I could find, a foot high, grew in the richest most shaded places along the river."

8. R. Fendleri, Crepin. Stems often tall (6 or 8 feet high, or less), with mostly rather slender straight or recurved spines, often scattered, or wanting: stipules and rhachis as in the last; leaflets 5 or 7 (very rarely 9), oblong to oblong-obovate, more or less cuneate at base and often petiolulate, usually glaucous, very finely pubescent beneath or glabrous or somewhat resinous, the teeth usually simple: flowers small, often solitary, the short pedicels, receptacles, and sepals glabrous, or the last subpubescent: fruit globose or broadly ovate, with little or no neck, about four lines broad. — Bull. Soc. Bot. Belg. 15. 452.

Hab. From Western Texas and New Mexico to the Sierra Nevada, and northward to beyond the British Boundary. — W. Texas, near Fort Davis (*Bigelow*); New Mexico, near Santa Fe (*Fendler*), on the Mimbres (*Thurber*), in the Raton Mountains (*Abert*), Sandia Mountains (*Bigelow*), S. Magdalena Mountains (*G. R. Vasey*), and at Mangus Springs (*Rusby*); Arizona, at Trumbull (*Palmer*), and Willow Spring (*Rothrock*); Utah (*Bishop, Ward*), near Salt Lake City (*Engelmann, Jones*); Nevada (*Sargent*), in the Goshoot Mountains (*H. Engelmann*), East and West Humboldt Mountains, etc. (*Watson*), Truckee Valley (*Bailey*), Carson City (*Anderson*); Eastern California, near Mono Lake (*Brewer*), head of Susan River (*Beckwith*), Sierra County (*Lemmon*), Modoc Range (*Sargent*); Oregon, Union County (*Cusick*), Hood River (*Henderson*), and at the Dalles (*Engelmann, Sargent*); Washington Territory, Klickitat County (*Suksdorf*), on the Yakima and Wenatchee (*Brandegee*), Okanagan Valley (*Watson*); Colorado, at Twin Lakes (*Wolf, Engelmann*), and at Hot Sulphur Springs, Middle Park (*Parry, Engelmann*); Wyoming, in the Wind River Mountains (*Fremont*), and on Hoback River (*Richardson*); Montana (*Howard*), at Gallatin City (*Scribner*), on Rock Creek in Bitter-Root Valley (*Watson*), and on Hudson

Bay Creek (*Sargent*); Wyoming, at Carbon (*Britton*); British Columbia, on the Kootanie Trail (*Dawson*).

The species was founded upon the resinous serrulate-toothed specimens collected by Fendler, a form common in Colorado and New Mexico, but the more widely distributed form is wholly without glandulosity. While closely approaching the more finely tomentose and smoother forms of *R. Californica*, it appears to be sufficiently differentiated from it by its more strictly globose fruit (the calyx raised upon a less prominent neck or closely sessile), the pubescence never villous, the receptacle and pedicel always glabrous and sepals never hispid, and the foliage more or less glaucous. The leaves are usually narrower and cuneate at base, never rounded or ovate. As a rule, and as in the other species of the group, the sepals are entire. In a few vigorous specimens, however, from near Salt Lake City, and from Klamath River, California, an occasional lobe is found on the outer sepals.

Specimens which may belong to a distinct species of this group have been collected near Pembina (*Havard*), in the high mountains of Montana (*Swallow*), and near Fort Colville, Washington Territory (*Watson*), distinguished by narrowly oblong fruit (8 to 10 lines long), on mostly solitary naked or hispid short pedicels, the stems (4 inches to 4 feet high) with very slender straight spines. A fuller series of specimens is needed.

+ + Outer sepals usually with one or more lateral lobes.

9. R. Woodsii, Lindl. Stems usually low ($\frac{1}{4}$ to 3 feet high), with slender straight or recurved spines, and sometimes with scattered prickles, or unarmed above: stipules narrow or dilated, entire; leaflets 5 or 7 (sometimes 9), obovate to oblong or lanceolate, rounded or acute at the summit, obtuse or usually cuneate at base, glabrous or subpubescent above, villous or finely pubescent or glabrous beneath (with the rhachis and stipules), simply toothed often only above the middle, sometimes resinous and serrulate-toothed, sometimes glaucous, usually small (the terminal $\frac{1}{2}$ to $1\frac{1}{2}$ inches long): flowers ($1\frac{1}{2}$ to 2 inches broad) corymbose or very often solitary, on very short naked pedicels; sepals naked or hispid, the lobes more or less conspicuous: fruit globose with a short neck, 4 or 5 lines broad. — Monogr. Ros. 21, and Bot. Reg. 12, t. 976. *R. Maximiliani*, Nees, Pl. Maxim. 8. *R. foliolosa*, var. *leiocarpa*, Torr. in Frem. Rep. 89.

Hab. Missouri to Colorado and northward to Western Montana, the Saskatchewan and Slave Lake, chiefly on the plains and in the valleys. — Missouri, Jackson County (*Broadhead*); Nebraska, on White River, Smith's Fork, and in the Bad Lands (*Hayden*); Colorado (*Parry, Hall & Harbour*), on the Platte (*Fremont*), near Denver (*Jones*), at Cañon City (*Brandegee*), at Colorado Springs and near Twin Lakes (*Engelmann*); Southeastern Idaho (*Allen*), and in Beaver Cañon (*Watson*); Montana (*Ward*), on Tongue River (*Roberts*), and in Grasshopper Valley (*Watson*); Dakota (*Nicollet, Culbertson*), at Fort Clarke (*Suckley*), and at Mandan (*Meehan*); Minnesota (*Sykes*), near Minneapolis (*Miss Butler, Upham*); Canada, on the Saskatchewan (*Bourgeau*), Slave Lake, etc. (*Richardson*).

Very variable, and in some of its forms nearly approaching *R. Fendleri.* The resinous-pubescent specimens are all from the Platte Valley in Colorado. In the more eastern localities the pubescence is often quite villous. The specific name was given in honor of Joseph Woods, an English botanist, who, according to Lindley, was the first to distinguish the species of roses by their true characters.

* * Receptacle densely prickly, and sepals pinnatifid.

10. R. MINUTIFOLIA, Engelm. Stems rigidly much-branched, 2 to 4 feet high, armed with numerous at length stout spines, usually terete above the base, straight and spreading or slightly recurved, and with scattered deciduous prickles; internodes of the branches very short: stipules usually very short and narrow, glandular-ciliate; leaflets 3 to 7, very small (the terminal 2 to 5 lines long), rounded to oblong-lanceolate, very coarsely and unequally toothed and the margin revolute, pubescent, less so above: flowers small (an inch broad), always solitary, and the very short pubescent or somewhat prickly pedicel bractless; sepals densely pubescent and with few prickles, shortly appendaged above, the outer pinnately lobed: fruit globose with a very broad orifice, densely prickly, 3 or 4 lines broad. — Bull. Torr. Bot. Club, 9. 97 and 127.

HAB. Lower California; hillsides near the coast, between Sauzal and Encenada on Todos Santos Bay (*Jones, Orcutt, Parry, Pringle*).

II. — Sepals spreading after flowering, deciduous. Infrastipular spines present (or wanting above), and the stems often more or less covered with scattered deciduous prickles.

A. — Styles distinct, numerous, persistent. Base of the calyx persistent on the globose fruit. Calyx, receptacle, and pedicel hispid. Teeth simple and pubescence not resinous, except in *R. Mexicana.*

* Pedicels usually elongated. Eastern species.

+ Leaflets finely many-toothed.

11. R. CAROLINA, Linn. Stems usually tall (1 to 6 feet high), with stout straight or usually more or less curved spines: stipules long and very narrow, naked or glandular-ciliate; leaflets dull green, 5 to 9 (usually 7), usually narrowly oblong and acute at each end and petiolulate, often broader and sometimes obtuse or acuminate, glabrous or pubescent, usually more or less pubescent beneath (with the naked or prickly rhachis), the terminal 1 to 2½ inches long: flowers corymbose or often solitary, the pedicels rarely naked; outer sepals with occasionally a small lateral lobe: fruit depressed-globose, 4 or 5 lines broad. — Syst. Nat. 10 ed. 1062; Meehan, Native Flowers, 1. 169, t. 43; Sprague & Goodale, Wild Flowers, 147, t. 35. *R. palustris*, Marsh. Arbust. 135. *R. corymbosa*, Ehrh. Beitr. 4. 21. *R. Hudsoniana*, Thory in Redouté, Ros. 1. 95, tt. 35, 112, 116.

HAB. Borders of swamps and along streams; from Nova Scotia to Ontario and Minnesota, and southward to Florida and Mississippi. — W. Vermont (*Pringle*); Massachusetts (*Oakes, Jesup, Robinson, Sargent, Watson*); Rhode Island (*Engelmann, Sargent*); Connecticut (*Wright, Jesup*); New York (*Gray, Brown*); New Jersey (*Torrey, Redfield*); Pennsylvania (*Pickering, Redfield, Green, Engelmann*); Ohio (*Riddell, Lapham*); Indiana (*Clapp, Short*); Illinois, on Illinois River (*Geyer, Engelmann*); Wisconsin, at La Pointe (*Engelmann*); W. Missouri (*Broadhead*); Kentucky (*Riddell, Short, Drummond*); Tennessee, at Nashville (*Gattinger*); Maryland (*J. D. Smith*); Virginia (*Rugel, Curtiss, Shriver*); District of Columbia (*Vasey*); N. Carolina (*Engelmann, J. D. Smith*); S. Carolina (*Mellichamp, Bachman*); Georgia (*Say, Wright*); Florida (*Leavenworth, Curtiss*); Mississippi (*Hilgard*). I have seen no specimens from Canada, but Macoun reports it as ranging from Nova Scotia and New Brunswick to the western part of Ontario; specimens from New Brunswick, sent as such, prove to be *R. lucida.* Upham also reports it from several localities in Minnesota, but as infrequent.

A species readily recognized by the fine serration of the leaflets, in connection with narrow stipules and usually hooked spines. Sometimes, however, some leaves may be found as coarsely toothed as in *R. lucida*, and as the two species are often found in New England growing together, hybrids may be expected to occur. The time of flowering is about two weeks later than in *R. lucida.* The hispidness of pedicel and fruit is sometimes deciduous, leaving them nearly smooth.

+- +- Leaflets coarsely toothed.

12. R. LUCIDA, Ehrh. Stems often tall (a few inches to 6 feet high), with at length stout straight or usually hooked spines: stipules usually naked, more or less dilated; leaflets dark green, rather thick, smooth and shining above, often slightly pubescent beneath and on the rhachis: flowers, fruit (4 to 6 lines broad), etc., nearly as in *R. Carolina;* outer sepals frequently with one or two small lobes. — Beitr. 4. 22. *R. laxa*, Lindl. Ros. Monogr. 18, t. 3. *R. Lindleyi*, Spreng. Syst. 2. 547.

HAB. Margins of swamps or moist places; from Newfoundland to Eastern New York and Pennsylvania. — Newfoundland (*Osborn*); Cape Breton (*Macoun*); Nova Scotia (*Macoun, Burgess*); New Brunswick (*Fowler, Vroom*); Maine, at Kennebunkport (*Jesup*); Vermont (*Pringle*); Massachusetts (*Oakes, Torrey, Robinson, Sprague, Sargent, Engelmann, Watson*), at Hadley (*Jesup*); Rhode Island (*Engelmann*); Eastern New York (*Nuttall*), at College Point, L. I. (*Schrenk*); Pennsylvania (*Read, Townsend*).

This as it shows itself in New England and eastward appears to be quite distinct both from the last and from the following species; still forms occur (especially in the herbarium) that are sufficiently troublesome to distinguish. The New York and Pennsylvania specimens, though very old and poor, belong here rather than elsewhere, as also some imperfect specimens from a swamp near Wytheville, Virginia (*Shriver*). Dr. Torrey, in his *Flora of the Northern and Middle States* gives as localities for this species only "mountain bogs, Fishkill Mountains, etc., New York; Williamstown, Mass.," but the single specimen from New York in his herbarium is too poor to show the distinguish-

ing characters of the species. In the later Flora of the State he considers this species and *R. humilis* identical. The range will probably prove to be somewhat more extended, but all herbarium specimens which I have seen from more western localities that have been referred to this species are clearly referable to *R. humilis*. The fruit is sometimes found oblong-obovate, but in all the cases that I have examined this has been a deformity caused by insects, and attended by a diminished number of seeds. Dr. Torrey in the *Flora of New York* attributes a like variation in *R. Carolina* to the same cause.

13. R. HUMILIS, Marsh. Stems usually low (1 to 3 feet) and more slender, less leafy, with straight slender spines, spreading or sometimes reflexed: stipules narrow, rarely somewhat dilated; leaflets as in the last, but usually thinner and paler, glabrous or usually more or less pubescent, especially beneath, and also the rhachis (often prickly): flowers very often solitary, the outer sepals always more or less lobed, often pinnately so: fruit as in the preceding. — Arbust. Amer. 136. *R. parviflora*, Ehrh. Beitr. 4. 21. *R. Lyonii*, Pursh, Fl. 345. *R. lucida*, Auct.; Meehan, Native Flowers, 2. 33, t. 9.

HAB. In dry soil and on rocky slopes and mountain sides; from Maine to Georgia and west to Wisconsin, Missouri, the Indian Territory, and Louisiana. — Maine (*Oakes*); Massachusetts (*Oakes, Jesup, Watson*); Connecticut (*Bishop*); New York (*Eaton, Nuttall, Eggert, Jesup*); New Jersey (*Read, Torrey*); Pennsylvania (*Lea, Read, Whitesides, Redfield, Wolle, Engelmann*); Maryland (*J. D. Smith*); District of Columbia (*Vasey, Ward*); Virginia (*Curtiss, Shriver*); N. Carolina, on Roan Mountain (*Gray*); Georgia (*Mrs. Say, G. R. Vasey*); Ohio (*Baldwin, Morgan, H. P. Smith*); Indiana (*Coulter*); Michigan (*Drake, Clarke, Gillman, Wheeler*); Ontario, Detroit River (*Gillman*); Wisconsin, Dane County (*Hale*); Illinois (*Short, Engelmann, Vasey, Brendel*); Missouri, St. Louis and Jefferson Counties (*Engelmann, Eggert*); Kentucky (*Riddell, Short*); Tennessee (*Gattinger*); Alabama (*Buckley, Kirk, Mohr*); Mississippi (*Hilgard*); Louisiana (*Hale, Carpenter*); Arkansas (*Nuttall, Fendler*); Indian Territory, at Limestone Gap (*Butler*).

A widely distributed and very variable species, but in general readily distinguished. The spines are usually very slender, but on more vigorous plants they may become stouter and somewhat flattened, but are always straight. In a few specimens the leaflets have been found doubly toothed.

14. R. NITIDA, Willd. Usually low, nearly or quite glabrous throughout, the straight slender spines often scarcely stouter than the prickles which cover the stem and branches more or less thickly: stipules usually dilated; leaflets bright green and shining, usually narrowly oblong and acute at each end, sometimes broader and obtuse, small (the terminal ½ to 1¼ inches long): flowers usually solitary (rarely 2 or 3), bright red (1½ to 2½ inches broad), the slender pedicel, receptacle, and calyx densely hispid or glandular-prickly; sepals entire: fruit globose, 4 or 5 lines broad. — Enum. 544; Lindl. Ros. Monogr 13, t. 2. *R. rubrispina*, Bosc.

HAB. Margins of swamps and damp woods; Newfoundland to New England. —Maine, Aroostook County (*Miss Furbish*), Kennebunkport (*Jesup*); Massachusetts, Ipswich (*Oakes*), Andover and Middleton (*Robinson*), Wellesley (*Sprague*), Granby (*Jesup*), S. Hadley (*Mrs. Frisbie*). Originally collected in Newfoundland.

A very pretty and distinct species.

* * Pedicels very short. Southwestern and Mexican species.

15. R. FOLIOLOSA, Nutt. Stems low (6 to 18 inches high), with very short straight or somewhat curved slender or stout spines, or often unarmed; prickles rarely if ever present: stipules narrow, usually glandular-ciliate; leaflets 7 to 11, narrowly or even linear-oblong (the terminal 4 to 15 lines long), acute at both ends, glabrous, or slightly pubescent on the midvein beneath and on the prickly rhachis: flowers (1½ to 2 inches broad) solitary (or 2 or 3), on nearly naked pedicels 2 to 4 lines long; sepals prickly-hispid, the outer with one or more lobes: fruit depressed-globose, 3 to 5 lines broad.— Torr. & Gray, Fl. 1. 460.

HAB. Prairies and hillsides; Arkansas and Indian Territory to Texas.— Arkansas (*Nuttall, Pitcher, Bigelow*); Indian Territory (*Woodhouse, Engelmann, Butler, Palmer*); Texas (*Drummond, Berlandier, Lindheimer, Hall, Reverchon*).

A very strictly defined species. The flowers are said to be very fragrant. The Florida specimens doubtfully referred to this species by Torrey & Gray are a small-leaved form of *R. Carolina*.

16. R. MEXICANA, Watson. Stems low (a foot high or less), with stout straight spreading spines and scattered prickles: stipules narrow, glandular-ciliate; leaflets 5 or 7, mostly narrowly oblong, acute at both ends (the terminal 4 to 8 lines long), glabrous above or nearly so, somewhat resinous beneath, doubly serrate, the rhachis hispid and prickly: flowers solitary on hispid pedicels 3 or 4 lines long; outer sepals with a lateral lobe; receptacle glandular-prickly and the globose fruit 3 or 4 lines broad.— Proc. Amer. Acad. 17. 354.

HAB. In the Caracol Mountains, Coahuila, Mexico (2124 *Palmer*).

B.—Styles connate into a slender smooth exserted persistent column. Sepals short, deciduous, the base of the calyx persistent.

17. R. SETIGERA, Michx. Stem very tall and climbing, with stout recurved scattered spines, without prickles: stipules very narrow, glandular-ciliate; leaflets 3 or 5, oblong-ovate to lanceolate, shortly acuminate, coarsely and simply serrate, smooth above, usually more or less tomentose beneath, 1 to 3 inches long; rhachis glandular-pubescent, sparingly prickly: flowers corymbose, sometimes solitary, on slender hispid pedicels, deep rose-color becoming white, nearly scentless; sepals hispid, lanceolate (4 to 6 lines long), usually with one or

two lateral lobes: fruit oblong-ovate to depressed-globose, 4 or 5 lines long. — Fl. Bor.-Am. 1. 295. *R. rubifolia*, Ait. f. Hort. Kew. 2 ed. 3. 260; Redout. Ros. 3. 71, t. 152; Lindl. Ros. Monogr. 123, t. 15. *R. fenestrata*, Donn. *R. mutabilis*, Bradbury.

HAB. From Ontario and Wisconsin to Northern Texas, and eastward to S. Carolina and Florida. — Ohio (*Short, Sullivant, H. P. Smith*); Illinois (*Mead, Buckley, Eggert, Hall*); Kentucky (*Short, Peter*); Missouri (*Baldwin, Beck, Broadhead, Lindheimer, Engelmann*); Arkansas (*Bigelow, Harvey*); Indian Territory (*Butler, Palmer*); Northern Texas (*Reverchon*); Louisiana (*Carpenter*); Alabama, Hale County (*Watson*), Mobile (*Mohr*); Georgia (*Chapman*); S. Carolina (*Bachman*). It is credited also to Ontario by Macoun, to Michigan by Torrey & Gray, Austin, Palmer, Wheeler, and Coleman, to Wisconsin by Gray, to Nebraska by Aughey, and to Florida by Chapman, but I have seen no specimens.

Extensively cultivated as Michigan or Prairie Rose, Baltimore Belle, Queen of the Prairie, etc. The more tomentose form is the var. *tomentosa*, Torr. & Gray (*R. rubifolia*, Ait. f.). The flowers are often very numerous, in compound corymbs, the petals varying from 6 to 15 lines in length. The teeth of the leaflets have occasionally a gland-tipped toothlet.

C. — Styles few, distinct, deciduous with the entire calyx from the very contracted top of the naked fruit. Sepals short, entire.

18. R. GYMNOCARPA, Nutt. Stem slender and rather weak, 2 to 10 feet high, with straight slender infrastipular and scattered spines, and more or less densely prickly, or nearly naked: stipules usually narrow, glandular-ciliate; leaflets 5 to 9 (usually 7), from round-elliptic and obtuse to narrowly oblong and acute, glabrous (rarely somewhat tomentose or resinous), doubly glandular-toothed, sessile or nearly so, usually small; rhachis more or less prickly and hispid: flowers solitary or few, on hispid or sometimes glabrous pedicels; sepals rarely hispid, usually 3 or 4 (rarely 6) lines long: fruit oblong-obovate (3 to 6 lines long) to globose (3 or 4 lines broad), few-seeded. — Torr. & Gray, Fl. 1. 461; Torr. Bot. Mex. Bound. t. 24. *R. spithamæa*, var. *subinermis*, Engelm. in Coult. Bot. Gaz. 6. 236.

HAB. From British Columbia to Monterey and the Yosemite, and in the mountains of Northern Idaho and northwestern Montana. — British Columbia, on Fraser River (*Lyall, Engelmann, Macoun*), and Vancouver Island (*Engelmann, Meehan*); Washington Territory (*Pickering, Brandegee*), at Seattle (*Engelmann*), Falcon Valley (*Suksdorf*), and Fort Colville (*Watson*); Western Oregon (*Douglas, Nuttall, Pickering, Hall, Engelmann, Sargent, Howell*); California (*Bigelow*, 94 *Bridges*, 225 *Kellogg & Harford, G. R. Vasey, Engelmann, Mrs. A. E. Bush*), at Yreka (*Greene*), Upper Sacramento (*Hooker & Gray*), Mendocino County and Oakland (*Bolander*), Napa Valley (*Torrey*), mountains above Chico (*Mrs. Bidwell*), Emigrant Gap (*Jones*), Silver Mountain (*Brewer*), at Sisson's (*Gray*), Monterey (*Parry*); Northern Idaho, at Cœur d'Alene Lake and in the Bitter-Root Mountains (*Watson*); Northwestern Montana, at head of Bitter-Root River (*Watson*), Flathead Lake (*Sargent*). It is said in the Botany of the Mexican

Boundary Report to have been collected at San Diego by Parry, and the specimens are so labelled in Herb. Torrey, but this is probably a mistake. Parry's specimen in Herb. Gray is labelled from "Monterey," and is a nearly exact counterpart, and perhaps the original, of the figure given by Dr. Torrey.

The flowers are pale rose-color, sometimes white, usually about an inch broad. The sepals are always entire and rarely with more than a slender acumination, the flower-bud being globose to broadly ovate. An unusual form was collected by me in Northwestern Montana, on the descent from the Rocky Mountains into Ross's Hole at the head of the Bitter-Root River, with larger flowers (2 inches broad), and the sepals as long as the petals. The leaflets vary much in form and size (the terminal 3 to 18 lines long), and frequently have many of the teeth entire. The var. *pubescens*, Watson, is the rare tomentose high-mountain form. Resinous pubescence on the under side of the leaves is more frequent, but still rare.

Naturalized Species.

* Deciduous Roses, introduced from Europe; flowers pink.

R. CANINA, Linn. *Dog Rose.* Stems armed with stout recurved spines, without prickles, the branches sometimes unarmed: stipules often dilated; leaflets 5 or 7, elliptical or oblong-ovate, often rounded at base, usually an inch long or less, glabrous or somewhat pubescent, simply toothed: flowers solitary (or 2 to 4) on usually naked pedicels; sepals pinnatifid, deciduous: fruit naked, oblong-ovate, rarely nearly globular. — *R. flexuosa*, Raf. *R. Montezumæ*, HBK., Nov. Gen. & Spec. 6. 222; Thory in Redout. Ros. 1. 55, t. 16.

HAB. Roadsides; Eastern Pennsylvania, Tennessee, and probably elsewhere; Mexico.

Readily distinguished from native species by the naked receptacles and pedicels, the small leaves usually obtuse at base, the ovoid fruit, etc. The very slender styles, also, are little exserted beyond the very contracted elevated opening of the receptacle. There can be little doubt that *R. Montezumæ* is only a naturalized form of this species. The specimens from Mexico in our herbariums that have been so named (from highlands west of the city of Mexico, *Gregg*, Monterey, *Coulter*, and Toluca, *Andrieux*) are not distinguishable from *R. canina*. It was referred to *R. canina* as var. *Montezumæ* by Seringe, and the same reference is made by Crepin after examining specimens from several other collectors and localities.

R. RUBIGINOSA, Linn. *Sweetbrier, Eglantine.* Resembling the last, but of more compact habit, the leaflets densely resinous beneath and aromatic, and doubly serrate; the short pedicels and pinnatifid sepals hispid; fruit subglobose to oblong-ovate. — *R. suaveolens*, Pursh, Fl. 346. *R. micrantha*, Smith.

HAB. From Nova Scotia to Ontario and southward to S. Carolina and Tennessee; Oregon.

R. micrantha, "midway between *rubiginosa* and *canina*" (Hooker), is less strongly scented, the branches longer, fruit narrower, and the styles glabrous.

* * Southern Evergreen Roses, from China. Flowers white.

R. LÆVIGATA, Michx. *Cherokee Rose.* Climbing, with very stout recurved scattered spines: stipules very short and narrow; leaflets 3, smooth and shining, very sharply serrulate: flowers large, solitary, the pedicels naked or prickly above; sepals entire, somewhat prickly, spreading and persistent: fruit very prickly, oblong-ovate with a long-attenuate base, an inch long or more. — Fl. Bor.-Am., 1. 295. *R. Cherokeensis*, Donn. *R. Sinica*, Lindl. Ros. Monogr. 126, t. 16 (not Murray, Aiton, etc.); Hook. Bot. Mag. t. 2847.

HAB. Very common in the Southern States, and often used for hedges.

R. BRACTEATA, Wendl. *Macartney Rose.* Stem armed with very stout curved spines and glandular-prickly, the branches, calyx, and fruit covered with persistent dense tomentum: stipules and bracts laciniate; leaflets 3 to 9, small, oblong-obovate or elliptical, very obtuse, crenulate-serrulate: flowers solitary, nearly sessile between the bracts: fruit globose.

HAB. South Carolina to Louisiana, but not common.

2. *Descriptions of some New Species of Plants, chiefly from our Western Territories.*

CIMICIFUGA LACINIATA. Tall: leaves thin, 3-ternate with the divisions 3-parted or deeply lobed, the acuminate segments coarsely laciniate-toothed, nearly glabrous: panicle thinly tomentose-pubescent; pedicels 1 to 6 lines long: petals usually present, and filaments unequal: ovaries 2 to 5, shortly stipitate, pubescent. — At Lost Lake on Mount Hood, Oregon, at 3,000 feet altitude. Collected by Mrs. P. G. Barrett, of Hood River, in September, 1882, and again in 1884, as also by Mr. L. F. Henderson, of Portland. Resembling *C. elata*, but the leaves more decompound, and the segments more acuminate and coarsely toothed. *C. elata* has also shorter pedicels (scarcely a line long), the flowers apetalous and filaments equal, and the one or two ovaries glabrous.

CIMICIFUGA ARIZONICA. Foliage similar to that of the last species, but the leaflets more attenuate at the apex: raceme simple, pubescent or glabrate, the pedicels mostly 1 or 2 lines long, or longer in fruit: petals none: stamens equal: follicles sessile, usually 2 or 3, pubescent, 6 lines long, compressed, many- (about 15-) seeded: seeds densely covered with conspicuous white scales. — In a ravine on the northwest side of Bill Williams' Mountain, Arizona, near the base; collected by

Mr. and Mrs. J. G. Lemmon, in August, 1884. These two western species, as well as *C. elata*, are distinguished from the eastern and Asiatic species of *Eucimicifuga* by the sessile or nearly sessile carpels. In *C. elata* the carpels are 4 lines long and about 10-seeded, the seeds brown and minutely tuberculate.

ARABIS SUBPINNATIFIDA. Biennial or apparently sometimes perennial, with a branching base, canescent with a very fine and dense stellate pubescence; stem 6 to 18 inches high: basal leaves crowded and persistent, very narrowly linear-oblanceolate, entire or sparingly toothed, $\frac{3}{4}$ to $1\frac{1}{2}$ inches long; cauline approximate, lanceolate, sessile and more or less sagittate, coarsely and subpinnatifidly toothed: flowers pale pink, 3 to 6 lines long: pods strongly reflexed on pedicels 2 to 5 lines long, $1\frac{1}{2}$ to $2\frac{3}{4}$ inches long and 1 to $1\frac{1}{2}$ lines wide, glabrous or pubescent, attenuate more or less narrowly to the short style. — West Humboldt Mountains, Nevada (76 Watson, in part, referred to *A. retrofracta*); Scott Valley, Siskiyou County, California, E. L. Greene, 1876; Waldo, Southwestern Oregon, Thomas Howell, 1884.

STREPTANTHUS HOWELLII. Apparently perennial, glabrous, the stout leafy simple stems a foot high or more: leaves from obovate-spatulate below to narrowly oblong-spatulate above, $1\frac{1}{2}$ to $\frac{1}{2}$ inches long: raceme elongated; pedicels 3 to 5 lines long: sepals broad, 3 lines long; petals with an oblong dark purple limb: stigma broad, very short and sessile: fruit unknown. — In the Coast Mountains, near the California line, in Curry County, Oregon; Thomas Howell, June, 1884. Evidently a *Streptanthus*, and of peculiar habit.

VESICARIA KINGII. Biennial and perhaps perennial, canescent with a close appressed-scurfy very obscurely stellate silvery pubescence, procumbent: leaves ovate, 2 to 6 lines long, upon an elongated slender petiole, becoming small and spatulate upon the short flowering stems (4 inches long or less): flowers pale yellow, 2 or 3 lines long: pods pubescent, ovate, obtuse, somewhat obcompressed (replum oblong), about 2 lines long, sessile upon the short pedicel (2 to 3 lines long): style $1\frac{1}{2}$ lines long or less. — West Humboldt Mountains, Nevada (82 Watson, referred to *V. montana*); Lassen's Peak, California, J. G. Lemmon, and Mrs. Austin; Aquarius Plateau, Utah, L. F. Ward (n. 589).

VESICARIA OCCIDENTALIS. Resembling the last in habit and pubescence: leaves oblanceolate, attenuate at base, 3 or 4 inches long including the petiole, mostly coarsely sinuate-toothed, the cauline spatulate-oblanceolate and mostly entire: stems decumbent, $\frac{1}{2}$ to 1 foot

long or more: flowers yellow, 4 lines long: pod compressed-globose (replum circular), 2 to 4 lines long, sessile upon a more or less flexuous pedicel 4 to 8 lines long: style very slender, about 2 lines long. — Near Yreka, California, E. L. Greene, 1876; Multnomah County, Oregon, T. J. Howell; White Bluffs of the Columbia, Washington Territory, T. S. Brandegee. The allied *V. montana* of the Rocky Mountains has the looser and less silvery pubescence evidently stellate, and oblong or oblong-ovate acute capsules.

DRABA (CHRYSODRABA) HOWELLII. Perennial with a branching cespitose base, the scape-like flowering stems about three inches high, sparingly stellate throughout: leaves rosulate, broadly spatulate, rarely obtusely toothed, 3 to 5 lines long: racemes loose, the large bright yellow flowers on slender ascending pedicels 3 to 5 lines long; sepals yellowish, 1½ lines long; petals 3 to 4 lines long: pod pubescent, oblong, acute, 4 or 5 lines long including the long slender style (a line long). — Siskiyou Mountains, California, Thomas Howell, June, 1884. Resembling forms of *D. alpina*, with larger deep-yellow flowers and longer long-beaked usually unsymmetrical pods.

ATAMISQUEA EMARGINATA, Miers (Trans. Linn. Soc. 21. 2, t. 1). This Capparidaceous species, originally discovered by Miers in the province of Mendoza, of the Argentine Republic, and credited to California in Coulter's collection, has been recently found by Mr. Pringle upon the sandy plains bordering the Altar River in Northwestern Sonora. It is here a large shrub, or sometimes a small tree, 15 or 20 feet high, and differing in no respect from the South American form.

CERASTIUM SERICEUM. Stems numerous, stout, 1 to 2 feet high, very leafy and densely silky-villous below, branching and glandular-pubescent above: leaves oblong-lanceolate, sessile, an inch or two long, the lower densely villous, the upper less so: panicle spreading and loosely flowered: sepals oblong or lanceolate, scarcely acute, 2 lines long, equalling the petals: capsule nodding, more than twice longer: seeds strongly tuberculate. — Collected in the Huachuca Mountains, Arizona, at 8,000 feet altitude, by Mr. and Mrs. J. G. Lemmon in 1882, and in the Santa Rita Mountains by C. G. Pringle in 1884. The seeds are twice larger and much more coarsely tuberculate than in *C. nutans*, to which it has been referred, though bearing little real resemblance to it.

ARENARIA (ALSINE) HOWELLII. A widely branching annual, about a foot high, glandular-hispid, but the internodes usually glabrous: leaves thick, narrowly lanceolate or linear with a clasping base, 6 to 9 lines long, blunt, spreading; bracts green, triangular-ovate to lanceo-

late: pedicels slender: calyx-lobes nerveless, margined, acutish, a line long; petals twice longer, narrowly oblong: capsule ovate, a little exceeding the calyx, 8-seeded: seeds nearly black, turgid, with several rows of minute tubercles along the rounded margins. — In the Coast Mountains, near Waldo in Southwestern Oregon, Thomas Howell, June, 1884. A stouter plant than *A. Douglasii*, and differing in its greater glandulosity, broader leaves and bracts, smaller flowers with nerveless calyx, and narrower capsule, and in the seeds.

TALINUM BRACHYPODUM. Perennial, the roots thick, elongated, not tuberous, and the caudex bearing several short leafy stems (1 to 2 inches long): lower leaves scale-like, the upper linear, 3 to 5 lines long: flowers few, axillary near the summit, on very short pedicels (1 or 2 lines long) jointed near the base: sepals acutish, 2 lines long, the bright pink petals twice longer or more: capsule ovate, 2 lines long. — A dwarf showy species allied to *T. aurantiacum*, with nearly sessile flowers. Found near the Indian village Laguna, or "Komack," in Northwestern New Mexico, by Mr. and Mrs. J. G. Lemmon, July, 1884.

CALANDRINIA OPPOSITIFOLIA. Root very thick and fleshy: radical leaves linear-oblanceolate, attenuate to the scarious-margined subterranean base, 1½ to 3 inches long, the lower cauline (1 to 3 pairs) opposite and similar, with occasionally scattered entire bracts above: stem 3 to 10 inches high, simple or branching, and bearing one or more terminal mostly 3-flowered umbels: pedicels elongated (1 to 3 inches long): sepals orbicular (3 or 4 lines long), acutely dentate but not glandular; petals 10, white or pinkish, 5 or 6 lines long: stamens 8 to 12 or more: style deeply 3-cleft: capsule oblong, 3 lines long, 5–10-seeded. — Collected by Thomas Howell at Waldo, Oregon, and in the Coast Mountains of Del Norte County, California, near Smith River.

CALANDRINIA COTYLEDON. Perennial, with thick roots and a stout rootstock crowned with a dense rosette of fleshy spatulate or oblanceolate leaves 1 or 2 inches long and ½ to 1 inch broad: scape-like stem bearing 2 or 3 lanceolate subscarious bracts below the short cymose panicle, 4 to 8 inches high; bracts glandular-ciliate; pedicels short: sepals orbicular, 2 lines long, many-nerved, the nerves excurrent and gland-tipped; petals 10, deep rose-color, oblanceolate, 6 lines long: stamens 7, equalling the petals, the filaments dilated below and somewhat coherent: style elongated; stigmas 3 or 2: ovary narrowly oblong, 1½ lines long, 3–4-valved; ovules 12 to 20. — A pretty and well-marked species, collected by Thomas Howell in the Siskiyou Mountains, Del Norte County, California, near the head of Illinois

River, June, 1884. Its resemblance in habit to small species of *Cotyledon* suggests the specific name. In this species, as in *C. Leana* and some others, the stigmas are often two, instead of three, and the capsule 2–4-valved.

CALYPTRIDIUM QUADRIPETALUM. Loosely branching from the base and prostrate, with broad spatulate leaves 1 to 3 inches long by 3 to 8 lines broad: racemes axillary and terminal, scorpioid and nearly naked: flowers nearly sessile and mostly imbricated, the round-reniform sepals conspicuously nerved and scariously margined, the longer 2 to 4 lines broad, exceeding the four oblong or round-ovate nearly equal petals: stigmas broad, nearly sessile: capsule oblong, 3 lines long, 12–20-seeded. — On the head-waters of Eel River in Lake County, California, Volney Rattan, June, 1884. It was also collected by Dr. Torrey in the same county in 1865, and referred in the Botany of California to *C. roseum*. It differs from the other species in the increased number of petals, and its broader sepals give it somewhat the appearance of *Spraguea*, which genus now rests only on its three exserted stamens and the elongated style.

MALVASTRUM FOLIOSUM. Stout, tall and erect, simple above and leafy to the summit, densely and coarsely stellate-pubescent throughout: leaves thick, broadly ovate, subcuneate at base, shortly or obscurely 5-lobed, the lobes acute and acutely dentate, 1½ to 2 inches long, on petioles a half-inch long; flowers nearly sessile in axillary nearly sessile panicles shorter than the leaves; bracts filiform: calyx 6 to 8 lines long, the lobes attenuate; petals purplish, little exceeding the calyx: carpels round-oblong, smooth, a line long. — Allied to *M. densiflorum*, more leafy above, more abundantly pubescent, the leaves not cordate at base, acutely lobed and toothed, the panicles somewhat less dense, and shortly peduncled. Found at Santo Thomas, on the coast of Lower California, by C. R. Orcutt, September, 1884.

SIDA ALATA. Erect, 3 to 6 feet high or more, branching, densely stellate-tomentose: leaves ovate to oblong-ovate, cordate at base, acute or obtusish, 1 to 2½ inches long, exceeding the petioles: pedicels slender, axillary, mostly solitary, exceeding the petioles, jointed above the middle: calyx-lobes acuminate; petals purplish, 5 lines long: carpels numerous, the small dark-colored triangular coriaceous body (1 line long) bicostate on the back, strongly reticulated on the sides, dehiscent at the summit and bearing two broad membranous crests 2 lines long: seed dark-colored. — A remarkable species on account of the early development of the upper portion of the valves of the carpels into free wing-like crests, in which respect it resembles *Cristaria*. But the

carpels do not separate from a persistent basal disk as in that genus, and there seems to be no good reason for excluding it from *Sida*. Collected by C. G. Pringle in Sonora, Mexico, about one hundred miles south of the boundary, in a low range of hills thirty miles frcm the Gulf.

Abutilon aurantiacum. Woody at base, the herbaceous stems ½ to 2 feet high, pubescent and somewhat villous: leaves densely soft-tomentose, velvety and whitish, round-cordate, acute, the rounded basal lobes overlapping, unequally serrate, ½ to 1½ inches broad, shorter than the petioles: flowers axillary and solitary, on villous-pubescent pedicels, which are as long as the petioles and mostly jointed near the base or the lower above the middle: calyx-lobes broadly ovate, acute; corolla bright orange, 6 to 9 lines long: calyx and fruit villous-pubescent; carpels 10, abruptly short-beaked, 3-seeded, 4 lines long, about equalling the calyx. — On Todos Santos Bay, Lower California, by C. C. Parry, January, 1883, and at Tia Juana, by C. R. Orcutt, in May of the same year.

Abutilon Parishii. Stout, branching from the base, the herbaceous stem (2 feet high or more), branches, and petioles more or less villous with reflexed hairs and tomentose: leaves on slender elongated petioles, covered with a dense fine apparently not stellate pubescence, white or whitish beneath, darker above, cordate-ovate with a deep narrow sinus, acute or acutish, coarsely and unequally toothed, 1 or 2 inches long: pedicels axillary, short, 2 to 6 lines long in fruit, jointed above the middle: calyx thinly tomentose, green, 3 lines long, the lobes lanceolate; petals orange, 4 to 6 lines long: carpels thinly pubescent, somewhat villous along the dorsal suture, 4 lines long, with a divergent narrow beak a line long. — On the foothills near Lowell, Arizona, W. F. Parish, May, 1884, and in the Santa Catalina Mountains, C. G. Pringle, April, 1884. Near *A. Wrightii*, but stouter, the leaves on longer petioles and more coarsely toothed, the pedicels shorter, calyx much smaller and less tomentose, etc.

Abutilon Lemmoni. Perennial, the stout half-woody branching stems 1 to 2 feet high, hoary throughout with a very dense short stellate pubescence, its stellate character scarcely perceptible on the calyx: leaves cordate to cordate-lanceolate, acute or slightly acuminate, dentate, the blade usually an inch or less (sometimes two inches) long, about equalling or shorter than the slender petioles, slightly greener above: peduncles axillary, solitary, shorter than the leaves, jointed near the top: calyx with broadly ovate acute lobes; corolla yellow or orange, small (3 to 4 lines long): carpels about 9, acute, 4 or 5 lines

long, finely pubescent, 3-seeded, equalling or a little exceeding the enlarged calyx. — On rocky hillsides near Santa Cruz, Sonora, Thurber (n. 943), 1851; Santa Catalina Mountains, Arizona, Lemmon (n. 130), 1881, and by Parish and Pringle, 1884; Northwestern Sonora, Pringle, 1884; Cedros Islands, Lower California, by Dr. T. H. Streets in 1876, and at Tia Juana, by Orcutt. Much resembling a species collected by Berlandier in Northeastern Mexico (n. 1550, 3050, and 3108; *A. Berlandieri*, Gray, in herb.), which, however, has more acuminate calyx-lobes, larger flowers, and more acuminate carpels with coarser stellate pubescence, the peduncles often several-flowered, and leaves usually more oblong and more acuminate.

Sageretia Wrightii. A shrub 2 to 5 feet high, with slender spreading pubescent branches and branchlets: leaves thin, bright green and shining on both sides, very sparsely villous on the midvein beneath, oblong or sometimes elliptical to lanceolate, acute or obtuse or sometimes emarginate, cuneate to subcordate at base, sparingly acutely serrulate, 4 to 8 lines or sometimes an inch long, with a short slender petiole: panicle very short (an inch long or less), often reduced to a short spike or even to a few flowers in the uppermost axils; sepals ovate, acute: fruit unknown. — Collected by Wright (n. 925) in 1851 at Santa Cruz, Sonora (referred to *S. Michauxii* in Pl. Wright. 2. 28, and in Hemsley, Bot. Biol. Cent.-Amer. 1. 200), by Dr. V. Havard at the Falls of Capote Creek, W. Texas, in October, 1883, and by C. G. Pringle on the foothills of the Santa Rita Mountains, Arizona, in July, 1884. *S. Michauxii*, of the Atlantic States, has smoother branches, more ovate and usually acuminate crenately toothed leaves, and more numerous flowers, with the calyx-lobes more lanceolate.

Rhus (Styphonia) ovata. A shrub, 5 to 10 feet high, glabrous excepting the finely pubescent branches and the bracts of the inflorescence: leaves coriaceous and shining, ovate, acute or acuminate, entire or rarely sparingly toothed, 2 or 3 inches long, on a stout usually reddish petiole 4 to 8 lines long: flowers in dense closely panicled spikes a half-inch long or less, the rounded bracts and sepals purplish; petals light yellow: fruit compressed-ovate, 2 or 3 lines long, viscid-pubescent. — On hills and mountains, away from the coast, from San Diego to Los Angeles County, the Cantillas Mountains in Lower California, and in Southern Arizona; also on Santa Catalina Island (W. H. Lyon). It has been confounded with the coast species *R. integrifolia* (and figured for it by Torrey in Pac. R. Rep. 7. 9, t. 2, excepting the single leaf), which has smaller obtuse and more frequently serrate leaves with shorter petioles, more pubescent, and with twice longer

fruit (5 lines in diameter). The broad usually very dense panicles are an inch or two long.

Lupinus (Platycarpos) Orcuttii. Diffusely much branched from the base, low (2 to 4 inches high), pubescent throughout with short stiffish spreading hairs: leaflets 5, oblong-spatulate, 3 to 6 lines long, shorter than the petioles: racemes numerous, sessile in the axils, 1 or 2 inches long, the scattered purple or reddish flowers 3 lines long: pod oblong, 4 lines long, 2–3-seeded: seeds a line in diameter. — Collected at Japa, in Lower California, near the boundary, by C. R. Orcutt, July, 1884. Allied to *L. pusillus*.

Hosackia (Syrmatium) nana. A dwarf prostrate very leafy and slender cespitose perennial, canescent throughout with short white spreading or subappressed hairs: leaflets 5 to 7, approximate, oblong-obovate, folded, a line long or less upon a slender petiole 1 or 2 lines long: peduncles shorter than the petioles, bearing 1 or 2 small flowers subtended by a small bract: calyx a line long, the teeth about half the length of the campanulate tube; corolla white or purplish, 2 or 3 lines long; ovary 1-ovuled. — On the mesa of Toyalani, near Zuñi, New Mexico; collected by Dr. W. Matthews, U. S. A., in 1883.

Dalea Orcuttii. Perennial, with numerous short slender herbaceous subprocumbent or ascending stems (3 or 4 inches long) from a woody branching rootstock, appressed silky-puberulent: leaves 4 to 6 lines long, the folded oblong-obovate leaflets (4 to 6 pairs) 1 or 2 lines long, glabrous above: peduncles about equalling the leaves; spikes short ($\frac{1}{2}$ inch long), somewhat crowded, the flowers reflexed or spreading: calyx short-villous, turbinate, the lanceolate acuminate teeth equalling or exceeding the tube; the purple orbicular banner and the wings scarcely exserted, the broad twice-longer keel purple on the inner margin. — At Topo and in the Cañon Cantillas, Lower California; collected by C. R. Orcutt, in October, 1882, and July, 1884. It was suspected that this might be the *D. canescens* of Bentham, collected at Magdalena Bay, but a comparison made by Prof. Oliver at Kew shows that, though allied to that species, it is not identical with it, the pubescence in *D. canescens* being of short somewhat sparse spreading hairs, and the calyx very small (1 line long).

Dalea (Xylodalea) megacarpa. Shrubby, densely white-tomentose throughout and conspicuously glandular-punctate: leaflets 5 or 6 pairs, suborbicular, retuse, $1\frac{1}{2}$ to 3 lines long: spikes rather dense, becoming 4 to 7 inches long; bracts narrowly linear, equalling the calyx: calyx turbinate-campanulate, with oblong obtuse teeth, shorter than the tube; petals yellow, becoming purplish brown, free and dis-

tinct, little exceeding the calyx (3 lines long), scarcely unguiculate: pod 4 lines long, 1–2-seeded: embryo green. — Collected by C. G. Pringle, April, 1884, in Northern Sonora, 150 miles south of the boundary, on the sandy beach at the mouth of a cañon opening out upon the Gulf of California, forming broad dense clumps two feet high. Distinguished from the other species of the group by the short bright yellow corolla. It is perhaps the "*Dalea* (?) *sp. n.*" of Benth. Bot. Sulph. 12, from the Bay of Magdalena, Lower California.

DALEA RUBESCENS, Watson (Proc. Amer. Acad. 17. 369). This species has been more recently collected in the mountains of Arizona by Lemmon and Pringle. Its stems are very rarely branched as they are in *D. aurea*, the leaflets (often pinnated) are narrower, the heads much stouter and denser, and the narrower bracts less conspicuous.

BRONGNIARTIA MINUTIFOLIA. A low shrub (1 to 3 feet high), much branched, the slender glaucous-green branchlets nearly glabrous: leaves 1 or 2 inches long, with slender rhachis, the herbaceous lanceolate stipules a line long; leaflets 10 to 20 pairs, linear, revolute, 1 or 1½ lines long: flowers solitary, on short naked peduncles (3 lines long); calyx 3 lines long, glabrous, persistent: pod glabrous, oblanceolate, 9 lines long, attenuate to a stipe about equalling the calyx-tube. — Found on the foothills south of the Chisos Mountains in Western Texas by Dr. V. Havard, U. S. A., in July, 1883.

ASTRAGALUS CONGDONI. Near *A. Andersoni*, more or less soft-pubescent, the decumbent stems about a foot long: leaflets 8 to 10 pairs, small and orbicular or obovate to oblong (1 to 4 lines long), retuse or obtuse: racemes open, on elongated peduncles: teeth of the campanulate calyx short and triangular; corolla pale yellow, 4 or 5 lines long: pod sessile, chartaceous, linear, curved, 2-celled by the intrusion of the dorsal suture, puberulent, nearly an inch long, somewhat compressed. — At Hite's Cove on the Merced River, Mariposa County, California, collected by J. W. Congdon, June, 1883. Distinguished from *A. Andersoni* by smaller and mostly broader leaves, less pubescence, shorter calyx-teeth, and a narrower less villous pod.

ASTRAGALUS ACUTIROSTRIS. Annual, slender, resembling *A. Nuttallianus:* leaflets 5 or 6 pairs, retuse, 2 or 3 lines long: racemes much exceeding the leaves in fruit: calyx a line long, the slender teeth about equalling the turbinate tube; corolla whitish, 2 lines long, the keel with an acute often ascending beak: pods (1 to 5) scattered on the rhachis, like those of *A. Nuttallianus*, but the ventral suture nearly straight, 8 lines long. — Near Brown's Ranch, Mohave Desert, by Parish Brothers, May, 1882, and on dry rocks above the Calico Mines,

near Fort Mohave, by J. G. Lemmon, May, 1884. Closely allied to *A. nothoxys*, Gray, but with much smaller flowers and calyx.

ASTRAGALUS ORCUTTIANUS. Stems numerous, slender, decumbent, a foot long, sparingly strigose-pubescent: leaflets 8 to 10 pairs, rounded, 1 to 3 lines broad: peduncles shorter than the leaves, 2 or 3 inches long in fruit; raceme loose, few-flowered: calyx campanulate, 2 lines long, the teeth mostly equalling the tube: pod linear-falcate, ascending, coriaceous, attenuate to a stipe shorter than the calyx, with a dorsal groove and acute ventral suture, 2-celled by the intrusion of the dorsal suture, 9 lines long. — Allied to *A. Arizonicus*, rather peculiar in habit, the small round leaflets upon an elongated rhachis exceeding the racemes. In Cantillas Cañon ("Tantillas" of Palmer), Lower California, by C. R. Orcutt, August, 1883.

ASTRAGALUS PROCUMBENS. Biennial or perennial, with numerous short procumbent and matted stems, canescent throughout with a short closely appressed straight pubescence: leaflets 2 to 6 pairs, oblanceolate to oblong-obovate or -oval, 2 to 5 lines long: peduncles usually exceeding the leaves, bearing a short few-flowered raceme: flowers spreading or reflexed; calyx campanulate, with narrow teeth several times shorter than the tube; corolla twice longer (about 3 lines long), yellowish to deep purple: pod sessile, thick-coriaceous, 1-celled, turgid with prominent ventral suture, and at length deeply impressed dorsal one, oblong, spreading, 6 to 8 lines long. — Near Fort Wingate, New Mexico, by Dr. W. Matthews, U. S. A., in 1882 and 1883, and near the Indian village of Laguna, Lemmon, 1884. Also previously collected by Dr. Palmer, but locality uncertain. Nearly allied to *A. humistratus*.

ASTRAGALUS MOHAVENSIS. Biennial, hoary throughout with short white strigose pubescence, the branching stems a foot long or less: leaves rather long-petiolate, the leaflets 2 to 4 pairs, obovate to oblong-obovate, 3 or 4 lines long, obtuse: raceme little exceeding the leaves, few-flowered: calyx turbinate, nearly 2 lines long, the slender teeth about equalling the tube; corolla 3 lines long, purplish: pod sessile, coriaceous, narrowly oblong, obcordate in cross-section, the ventral suture slightly curved and very prominent, more or less sulcate on the back and 2-celled by the intrusion of the dorsal suture, 8 to 11 lines long, acute. — In a cañon south of Newberry Spring in the Mohave Valley, in large depressed masses, by Mr. and Mrs. J. G. Lemmon, May, 1884. Allied to the last and to *A. humistratus*.

ASTRAGALUS CASTANEÆFORMIS. Biennial or perennial (?), densely cespitose, with numerous branching prostrate and decumbent stems

2 to 4 inches long: leaflets 4 to 8 pairs, oblong-obovate, 3 or 4 lines long, appressed silky-pubescent, acute or obtuse: peduncles equalling or exceeding the leaves (2 or 3 inches long); racemes short, loose; flowers ascending: calyx tubular, 4 lines long, with short slender teeth; corolla purplish, twice longer: pod coriaceous, ovate with a rounded base, more or less depressed when mature and somewhat sulcate on the ventral side, 1-celled, sessile, 6 to 9 lines long and 4 to 6 broad, silky-pubescent. — Near Williams' Station, Arizona, by Mr. and Mrs. J. G. Lemmon, July, 1884. Of the *Scytocarpi* group; the shape of the pod nearly that of our native chestnut, though it is somewhat smaller.

ASTRAGALUS TROGLODYTUS. Biennial or perennial (?), the rootstock bearing several crowded stems an inch long or less: leaves long-petioled, 4 inches long; leaflets 6 to 8 pairs, oblong-obovate, 4 or 5 lines long, acute or obtuse, strigose-pubescent: scape-like peduncles much exceeding the leaves (6 to 8 inches long); racemes short, dense; bracts persistent (2 or 3 lines long) and reflexed: flowers small; calyx campanulate, 2 lines long, the slender teeth half the length of the tube; corolla twice longer: pod subglobose, coriaceous, sessile, 1-celled, scarcely exceeding the calyx (2 or 3 lines long), silky-pubescent, 2–6-seeded. — In the San Francisco Mountains, Arizona, near "Cliff-dwellers' Ravine," Mr. and Mrs. J. G. Lemmon, August, 1884. A species of the *Scytocarpi* group, strongly marked by its scapose habit in connection with its small flowers and very peculiar pod.

ASTRAGALUS FALLAX. Perennial, with slender decumbent flexuous stems a foot long or more, canescently pubescent: leaves sessile, short; leaflets about 8 pairs, oblong to obovate, 2 to 6 lines long, obtuse or retuse: peduncles much exceeding the leaves; raceme loose; flowers reflexed: calyx campanulate, 2½ to 3 lines long, with very short teeth; corolla purplish, half an inch long: pod very shortly stipitate, subcoriaceous, oblong-ovate, turgid, somewhat depressed and sulcate when mature, acute at each end, 1-celled without intrusion of the sutures, 8 to 11 lines long including the stipe, and 3 or 4 lines broad, spreading or deflexed. — In Western New Mexico, collected by Wright (n. 1004) and by Sitgreaves, and at Flagstaff near the San Francisco Mountains, Arizona, by Rusby, and also by Lemmon. It has long been confused with *A. Fendleri*, and Wright's specimens were made the basis of the revised description of that species in Pl. Wright. 2. 24, which has been mainly followed in later works. The real A. FENDLERI, collected by Fendler, Parry, and Rothrock, in New Mexico and Colorado, has less pubescence, narrower leaflets, somewhat smaller

flowers and narrower calyx, and a much narrower pod attenuate to the base but not stipitate. A. GRACILENTUS is very similar to *A. Fendleri*, but the broader and shorter pod is not attenuate below, and is strictly sessile. A. GREENEI, Gray, is another nearly related species, having a shorter and more pubescent calyx (2 lines long) and shorter corolla, and the somewhat shorter pod strictly sessile.

DESMODIUM ARIZONICUM. Perennial, the herbaceous stems erect, 3 feet high or more, more or less coarsely pubescent; branches slender, elongated; leaves nearly sessile, 3-foliate; stipules linear-lanceolate, acuminate; leaflets linear-oblong (the lower narrowly oblong), obtuse or acutish, strigose above, more loosely hairy beneath, 1 to $2\frac{1}{2}$ inches long: flowers small (2 or 3 lines long), on filiform spreading pedicels ($\frac{1}{2}$ inch long) in elongated racemes: pod slightly pubescent, the joints suborbicular.— Collected by J. G. Lemmon in Arizona in 1881 (n. 540), and in the Santa Rita Mountains by C. G. Pringle, 1884. Closely allied to *D. sessifolium* and *D. Hartwegianum*, differing from the first in its greater pubescence, less acute leaflets, longer racemes and pedicels, and less pubescent pods,— from the latter in its narrower leaflets, branching inflorescence, much smaller flowers, etc.

LATHYRUS CALIFORNICUS. Stem stout, tall and more or less winged: stipules semi-sagittate, dilated and often coarsely toothed, or the upper narrower; leaflets 3 to 7 pairs, ovate-oblong to linear-lanceolate, $\frac{1}{2}$ to 2 inches long or more, acute or acuminate, softly pubescent on both sides, as also the rhachis: peduncles stout, nearly equalling the leaves, many-flowered: calyx-teeth short (the lower 2 lines long or less); petals 7 to 9 lines long, apparently yellowish or pinkish: pod linear, 2 inches long by 3 lines broad, attenuate at base to a stipe.— Along creek-banks in the valleys and foothills of California; referred doubtfully in the Botany of California (as by Dr. Torrey) to *L. venosus*, as var. *Californicus*. That eastern species, which reaches the Saskatchewan region and Lake Winnipeg, does not appear west of the Rocky Mountains. It has broad obtuse or retuse (rarely acute) leaflets, narrower stipules, smaller purple flowers, and the pods less attenuate at base.

LATHYRUS BOLANDERI. Stems usually stout and tall, wingless; glabrous throughout or the calyx only ciliate: stipules dilated, semi-sagittate, often toothed; leaflets 3 to 5 pairs, oblong-lanceolate to broadly ovate, obtuse or retuse or acute, $\frac{1}{2}$ to $1\frac{1}{2}$ or 2 inches long: racemes about equalling the leaves, 8–10-flowered: calyx-teeth broad, the lowest elongated; petals purple, 6 to 9 lines long: pods linear,

attenuated to the base, 2 to 2½ inches long, 3 or 4 lines broad. — In thickets, Oakland Hills, Bolander and Dr. Torrey in 1865; Angel Island, G. R. Vasey, 1876; Del Norte County, T. J. Howell, 1884; Butte County, Mrs. John Bidwell, a very broad-leaved form; Union County, Oregon, W. C. Cusick. This species has been confounded with the last, but may be distinguished by the want of pubescence, the less narrow and often obtuse leaves, the longer calyx-teeth, and purple flowers.

Calliandra Schottii, Torrey in herb. This species, which is doubtfully referred in the Botany of the Mexican Boundary to *C. Portoricensis*, has been again collected by Mr. Pringle in the Santa Catalina Mountains, Arizona, but still without fruit. The specimens are finely pubescent throughout, branches elongated, the leaflets 4 to 7 pairs, acutish, 2 or 3 lines long, and stipulates subulate, 1½ lines long; otherwise as described by Dr. Torrey.

Cowania Havardi. A much-branched shrub, 2 or 3 feet high, with rough grayish brown bark: leaves distichously fascicled at the ends of the numerous very short branchlets, entire, revolute-terete, white-tomentose below, glabrous above, spinulose-apiculate, 2 or 3 lines long: flowers solitary on the branchlets, shortly pedicellate; calyx-tube glandular-hispid, the short lobes oblong-ovate; petals white or yellowish, 3 or 4 lines long: carpels 8, with the plumose tails an inch long or less. — On a rocky mountain west of Tornillo Creek, W. Texas, by Dr. V. Havard, U. S. A., August, 1883, in flower and fruit.

Horkelia sericata. Perennial, cespitose, not glandular: radical leaves densely white-silky, the numerous crowded leaflets 2 or 3 lines long, oblong or obovate, unequally bifid: flowering stems slender, a foot high, the few short leaves with linear entire or bifid leaflets; cymes open and few-flowered: calyx silky, with narrowly lanceolate acuminate lobes, the narrower appendages nearly as long; petals narrowly obcordate, white tinged with pink: stamens 10, subulate, short: carpels 5; styles filiform: receptacle somewhat villous. — On the summit of the Coast Range in Curry County, Southwestern Oregon, by Thomas Howell, June, 1884.

Ivesia pinnatifida. Caudex thick, with very short stout branches: leaves pinnate, villous, the leaflets (½ to 1 inch long) deeply pinnatifid and segments linear: stems sparingly leafy, bearing an open panicle, 6 inches high; flowers solitary, on pedicels nearly a half-inch long: calyx-lobes lanceolate, the accessory lobes slightly narrower and shorter: stamens 20: carpels numerous. — Abundant in meadows

near Flagstaff, Arizona, by Mr. and Mrs. J. G. Lemmon, September, 1884, in fruit.

IVESIA LEMMONI. Branches of the caudex rather slender: leaves silky-villous, the leaflets (3 to 5 pairs) linear-oblong, tridentate at the apex, about an inch long: flowering stems slender, a foot high, bearing one or two small leaves, the panicle very loose and spreading, sparingly pubescent; flowers solitary on slender pedicels: calyx-lobes lanceolate, acuminate, twice longer than the linear appendages; petals yellow, obovate, little exceeding the calyx: stamens 15: carpels 3 to 5; receptacle very villous. — On vertical rocks bordering Oak Creek, near Flagstaff, Arizona, collected by Mr. and Mrs. J. G. Lemmon, August, 1884. Resembling *Horkelia tridentata* in its tridentate (though narrower) leaflets, but a true *Ivesia*, and differing from that species also in its open panicle, more attenuate sepals, yellow petals, and more numerous stamens. Only a few plants were found.

HEUCHERA RACEMOSA. Glandular-hispid: leaves reniform-cordate, crenately lobed and toothed, 1 or 2 inches broad: flowering stems 4 to 10 inches high, bearing 2 or 3 petiolate leaves and a loose few- (6–15-) flowered raceme; pedicels short (a line long or less): calyx very broadly campanulate, 2 (becoming 3) inches long, acutely lobed; petals glandular, linear, entire and acuminate or more or less laciniately toothed toward the top, a little exceeding the calyx-lobes: stamens 5, very short, opposite to the calyx-lobes: styles very short; capsule subglobose, very shortly beaked: seeds very numerous, brownish, with wrinkled testa, not muricate. — On cliffs of Mount Adams, Washington Territory, at 7–8,000 feet altitude, by W. N. Suksdorf, July, 1883. With the habit of *H. Hallii*, but the stem leafy and the inflorescence more strictly racemose, and peculiar in its frequently toothed petals.

SEDUM STELLIFORME. Branching from a stout fleshy base, with fleshy-fibrous roots; stems 2 to 4 inches high, leafy, simple or branched: leaves lanceolate to linear, 2 to 4 lines long, scattered: branches of the inflorescence (2 or 3) ½ to 1 inch long; pedicels very short: petals white tinged with purple, 2 or 3 lines long, equalling the stamens, twice longer than the lanceolate sepals: mature carpels divaricately divergent, usually lined with purple, 2 lines long. — In the Huachuca Mountains, Southern Arizona (2702 Lemmon, 1882), and near Fort Wingate, New Mexico, by Dr. W. Matthews, U. S. A., in 1883.

CUPHEA GLUTINOSA, Cham. & Schlecht. A slender glandular-pubescent perennial, with decumbent or ascending stems a span high:

leaves lanceolate (or the lower ovate-lanceolate), acute, sessile or very shortly petiolate, 3 to 6 lines long: flowers alternate, the very short pedicels lateral, with a pair of minute bractlets near the middle: calyx 3 or 4 lines long, with a very short broad spur; teeth nearly equal, and tube pubescent within; petals purple, 3 lines long; stamens 11, nearly or quite equalling the tube: capsule gibbous, 2 lines long, about 10-seeded: seeds nearly a line broad, with a narrow thick margin. — Specimens, thus referred by Koehne, have been collected by Mr. A. B. Langlois in low grassy places along Vermillion Bayou, near Vermillionville, Western Louisiana, April, 1884. The species is otherwise known only from S. America (S. Brazil and Buenos Ayres to Bolivia), but the evidence is all in favor of its being indigenous where it was found in Louisiana. Koehne, in his monograph of the *Lythraceæ* (Engler's Botanische Jahrbücher, 2. 148), describes the seeds of this species as having a thin narrow wing, a character which he uses in forming his groups. In a recent letter he admits that he has found this character inconstant, and of little value even for distinguishing species. The above description is drawn from Louisiana specimens.

Œnothera Havardi. Perennial, with branching caudex and numerous short slender simple or branching stems, canescent with short close pubescence: leaves linear-lanceolate, attenuate at each end, irregularly sinuate-pinnatifid, ½ to 2 inches long: flowers axillary, sessile, erect in the bud, puberulent; calyx-tube 1½ to 2 inches long, slightly dilated above, the attenuate tips of the lobes coherent; petals orange-yellow turning red, oblong-lanceolate, acute, a half to one inch long: stigmas short (1 or 2 lines long): capsule oblong-ovate, 4-angled and the valves strongly ribbed, about 5 lines long. — Collected on prairies near Morfa, Western Texas, by Dr. V. Havard, U. S. A., July, 1883. Scanty specimens were also collected by Mr. Wright in 1851 in a prairie-dog town near Leon Springs. A peculiar species of the *Euœnothera* section, not falling readily into any of the recognized groups, but perhaps most nearly related to *Œ. canescens*.

Hauya Californica. Shrubby, erect (6 to 8 feet high), the slender branches grayish: leaves somewhat fascicled, narrowly oblong-lanceolate, acute, 3 to 6 lines long, canescently puberulent: flowers in terminal racemes with small leafy bracts, shortly pedicellate, bright scarlet; calyx-tube cylindrical, 8 to 12 lines long, the lanceolate lobes equalling the obovate petals (3 lines long): stamens in two unequal series, the outer equalling the petals; anthers scarcely apiculate: stigma discoid: capsule narrowly oblong, 6 to 9 lines long, long-persistent. — On Cedros Island, Lower California; collected by Dr.

John A. Veatch in 1859, and again by L. Belding in 1881. It was described by Dr. Kellogg from Veatch's specimens as *Œnothera arborea* (Proc. Calif. Acad. 2. 32), and figured by him under that name in the "Hesperian." The seeds are described by him as "appendiculate"; the well-developed ovules are conspicuously winged at the upper end. It is a strongly marked species in this Mexican and Guatemalan genus, the three other species of which are described and figured by Hemsley, in Biol. Cent.-Amer., Bot. 1. 462, t. 29.

MENTZELIA (BARTONIA) BRANDEGEI. Stem branching, a foot high: leaves linear, pinnatifid with narrow lobes, 1 to 3 inches long; the bracts on the short pedicels mostly entire, very narrow: flowers in open corymbs: calyx-lobes 6 to 8 lines long, the five narrowly oblanceolate petals an inch long or more: stamens about 30, a little shorter, none petaloid: capsule narrowly oblong (7 to 9 lines long by nearly 3 lines wide): seeds horizontal, flattened, with somewhat angular or rugose sides and narrow scarcely winged margin. — Near the Simcoe Mountains, Washington Territory, on the mesa bordering Satas Creek; collected by T. S. Brandegee in 1883. Allied to *M. Wrightii*, *M. pumila*, etc.

MENTZELIA (BICUSPIDARIA) INVOLUCRATA. Annual, branching from the base, stout, a foot high or less, white-caulescent: leaves coarsely sinuate-dentate, linear- to oblong-lanceolate, the lower attenuate to a short petiole, the rest sessile and mostly cordate-amplexicaul at base: flowers terminal, solitary and sessile, involucrate with a pair of very broadly ovate acute or acuminate scarious bracts, the green margin coarsely toothed: petals pale yellow, an inch long, oblanceolate and cuspidately acuminate; stamens very numerous and slender, 3 to 6 lines long, the outer dilated above and continued into a long linear cusp on each side of the anther: style tubular, equalling the longer stamens, with three flattened stigmatic lobes at the summit: capsule about 9 lines long by 3 or 4 broad at the top, dehiscing by three apical valves: seeds in one row on each thin placenta, horizontally flattened but not margined, irregularly rugose and very minutely and densely tuberculate. — In San Bernardino County, California, by C. C. Parry in 1876; near Wickenburg, Arizona, by Dr. E. Palmer (n. 598 of his 1876 collection, distributed as *M. tricuspis*), and at Yucca, by M. E. Jones; and in Northwestern Sonora, by C. G. Pringle in 1884. Resembling *M. tricuspis* and *M. hirsutissima*, with which it forms a section (*Bicuspidaria*), distinguished especially by the bicuspidate outer filaments, etc., as has already been indicated under the latter species in Proc. Amer. Acad. 12. 252.

Cereus (Lepidocereus) Pringlei. Stems erect, irregularly branching above the base, and the branches also often divided, very stout and reaching a height of 20 or 30 feet or more, jointed; ribs usually 13, very rarely more; areolæ contiguous upon the ribs, oblong or lanceolate, the younger densely tomentose and with an outer circle of nearly erect more or less unequal ash-colored spines (mostly 6 to 9 lines long) and a central stouter one twice longer, all terete; the older areolæ naked, with about 15 dark flattened spines, mostly widely spreading, about an inch long, and deciduous: flowers lateral and scattered below the summit of the stem, 2½ inches long, the ovary and tube very densely covered with tawny hairs nearly or quite concealing the lanceolate scales and outer sepals; petals spatulate, white tinged with green or purple, 6 lines long: fruit globose, 2 inches long, bearing the persistent flower and densely covered with globose cushions (4 or 5 lines in diameter) of dense tomentum intermixed with more or less numerous white bristly spines (½ inch long or less): seeds black and shining, obliquely oblong-ovate, 1½ lines long; hilum oblong, basilar.—This very interesting addition to the *C. giganteus* group was found by Mr. C. G. Pringle scattered over the hills and mesas south of the Altar River in Northwestern Sonora, within 75 miles of the boundary. It is of more ponderous habit than *C. giganteus*, and scarcely equalling it in height, with numerous branches starting within two or three feet of the ground. The number of ribs is fewer than in that species, and the flowers are not borne clustered at the summit, but scattered along the ribs for two or three feet below the top. The grooves are about two inches deep, and the ribs upon all the older portions of the branches have usually become quite thornless. The fruit (only remains have been collected) seems to burst irregularly at one side, or perhaps is altogether indehiscent.

Carum Oreganum. With the habit of *C. Gairdneri;* lower leaves more divided, with shorter linear lobes: fruit oblong, 1½ lines long or more. — On "Wappatoo Island," Oregon, by Nuttall (*Edosmia Oregana*, in herb.); E. Hall (n. 203); Union County, Oregon, by W. C. Cusick; East Humboldt Mountains, Nevada, by Watson (n. 442, in part) in 1868. The fruit of the more widely distributed *C. Gairdneri* is ovate and shorter, a line long or but little more. Both are perennial, perpetuating a series of tubers for several years.

Cymopterus bipinnatus. Cespitose, the short branches of the rootstock covered with the crowded remains of dead leaves, glaucous, rough-puberulent: leaves pinnate with 4 or 5 pairs of short (3 to 5 lines long or less) subequal leaflets, which are pinnately divided, the

segments linear and entire or cleft into short linear lobes; scape slender, 4 to 6 inches high, much exceeding the leaves; rays of the umbel short (1 to 4 lines); involucels of several linear-lanceolate bracts: flowers white: fruit nearly sessile, 1½ or 2 lines long; the wings thin, but somewhat corky, narrow; vittæ 3 or 4 in the rather broad intervals. — In the Rocky Mountains south of Virginia City, Montana, by Prof. Hayden in 1871 (*C. fœniculaceus*); on a ridge above Bannock City, S. W. Montana, Watson in 1880, and on Mount Helena, Montana, W. M. Canby in 1883. Resembling *C. alpinus*, which is glabrous and more dwarf, the scape scarcely exceeding the leaves, and the fruit with very thick corky wings.

PEUCEDANUM SUKSDORFII. Very stout and tall (2 to 3 feet high or more), glabrous: leaves very large, decompound, the segments linear, 1 or 2 inches long, entire or mostly 2–3-cleft toward the top: rays 2½ to 5 inches long: involucels of numerous (6 to 12) linear acuminate bracts: flowers yellow: fruit narrowly oblong, 9 to 14 lines long by 3 to 6 broad, prominently ribbed, the large vittæ filling the intervals. — On dry rocky mountain-sides, W. Klickitat County, Washington Territory; collected by W. N. Suksdorf, June and July, 1883. Very remarkable among western species for the size of all its parts.

PEUCEDANUM HOWELLII. Acaulescent, glabrous: radical leaves biternate to biquinate, the leaflets cuneate-orbicular to round-cordate, acutely dentate, often 3-lobed, 6 to 12 lines long: scape 12 to 18 inches high: the fertile rays of the umbel few, elongated and divaricate; bracts of the involucel green, stout, acuminate-lanceolate: calyx of sterile flowers prominently toothed: fruiting pedicels few, 4 lines long: fruit broadly elliptical or nearly orbicular, 4 lines long; vittæ 3 or 4 in the intervals and 4 to 6 on the commissure. — Collected near Waldo, Josephine County, Oregon, by Thomas Howell, June, 1884. Of the *P. Euriptera* group.

ANGELICA DAWSONI. Rather slender, 1 to 3 feet high, glabrous or nearly so; stem simple: radical leaves biternate, the lanceolate leaflets 1 or 2 inches long, sharply and finely serrate, acute or acuminate, the terminal one sometimes deeply 3-cleft; cauline leaves (1 or 2 or none) similar: umbel solitary, conspicuously involucrate with numerous foliaceous lacerately toothed bracts nearly equalling the rays; involucels similar: rays short (about an inch long): fruit glabrous, 2½ lines long; vittæ solitary in the intervals. — Collected by Dr. Lyall in 1861 in the Rocky Mountains near the boundary, at 6,500 feet altitude, and on the slopes of the North Kootanie Pass by Dr. G. M. Dawson of the Canadian Geological Survey in 1883.

Boerhaavia bracteosa. Near *B. spicata:* annual, glandular-pubescent and viscid, two feet high, leafy below: leaves ovate-lanceolate to lanceolate, undulate, acute or acutish, subcordate at base, 1 to 1½ inches long besides the petiole: flowers spicate on the slender branches of the panicle; bracts conspicuous, pink, oblong-lanceolate, acuminate, 1½ lines long, persisting as long as the fruit or longer: perianth small (a line long): stamens 3: fruit oblong-obovate, obtuse, rather acutely 4–5-costate, the intervals somewhat pitted, a line long. — In the Great Cañon of the Rio Grande, Western Texas, by Dr. V. Havard, September, 1883. Distinguished from *B. spicata* by its more viscid pubescence, longer and more persistent colored bracts, and the broader fruit more acutely costate.

Atriplex julacea. Perennial, the slender woody stems procumbent, and the numerous short slender branchlets ament-like from the crowding of the close leafy undeveloped buds, scurfy-pubescent: leaves small, ovate-triangular, sagittate and clasping, thick, the larger cauline 2 lines long, those upon the branchlets scarcely a half-line long and sulcate from the folding back of the margins: fruit mostly solitary in the axils, 2 or 2½ lines long, the ovate marginless rigid bracts united to above the middle, and densely covered with irregular corky appendages. — Collected by C. R. Orcutt at Todos Santos Bay, Lower California, September, 1884. Related to *A. polycarpa*.

Eriogonum (Eueriogonum) suffruticosum. Perennial, very much branched and woody, low (4 to 6 inches high), canescent: leaves finely silky-tomentose both sides, fascicled and more or less revolute, oblanceolate, acute, attenuate to a short petiole, 2 to 4 lines long: peduncles simple or sparingly dichotomous, an inch long or less, bracteate, the bracts small and foliaceous, linear; involucres herbaceous, solitary, turbinate-campanulate, 6-cleft to below the middle, the lobes erect: flowers few, small (a line long), glabrous, pinkish, the outer segments of the perianth round-reniform, at length reflexed, the inner oblanceolate, obtuse, erect. — On the foothills of the Bofecillos Mountains, Western Texas; collected by Dr. V. Havard, September, 1883. A peculiar species, most nearly allied to some species of the *Umbellata* group, as *E. thymoides* and *E. sphærocephalum*.

Eriogonum vagans. (*Oxytheca inermis*, Watson, Proc. Amer. Acad. 12. 273.) Very near *E. hirtiflorum*, Gray, but less diffusely and finely branched, the branches more decumbent, and the flowers and akenes two or three times larger (half a line long). Both have similar ciliate leaves, unilateral foliaceous bracts, glandular pubescence, villous flowers, and obtusely triangular akenes. — In the San Ber-

nardino Mountains (W. G. Wright and S. B. Parish), and Mohave Desert (Mrs. K. Curran). The original locality is uncertain. *E. hirtiflorum* is more northern, ranging from Tuolumne to Lake and Colusa Counties. This species was at first upon a young and very insufficient specimen referred to *Oxytheca*, which genus appears to be clearly separated from *Eriogonum* only by the awned lobes of the involucre.

Eriogonum (Oregonium) giganteum. Of the *Corymbosa* section: a stout and tall shrubby perennial, bearing its leaves at the ends of the branches, which are tomentose or glabrate: leaves oblong, truncate or subcuneate at base, obtuse, 2 to 4 inches long including the stout petiole, pinnately nerved, densely tomentose, white and reticulately veined beneath, greener above: peduncle stout, bearing a broad dense dichotomously branched tomentose cyme, the foliaceous bracts lanceolate to linear: involucres sessile (the alar pedicellate), narrowly campanulate, densely tomentose, nearly a line long, cleft to the middle, the teeth lanceolate and acute; flowers small, tomentose, whitish, the oblong lobes green-nerved. — Found on the northwest coast of Santa Catalina Island, California, on rocky bluffs overhanging the sea, by W. S. Lyon, July, 1884. It is described as from 5 to 10 feet high and as much in diameter, the main stem sometimes 4 or 5 inches in thickness a foot above the ground, with thin fibrous bark and the cymes often 18 inches broad. It is allied to *E. corymbosum*, and especially to *E. arborescens*, Greene, which has linear sessile leaves and a broader involucre with broader and shorter teeth.

Eriogonum (Oregonium) Orcuttianum. Of the *E. Heermanni* group: the very short herbaceous leafy stems from a woody base, and the rigid divaricate branches finely subtomentose-pubescent: leaves scattered, thick, nearly glabrous, broadly ovate or obovate, obtuse, shortly petiolate, 3 to 8 lines long; bracts ternate, deltoid-subulate, small, subherbaceous: involucres solitary, turbinate-campanulate, subtomentose, nearly a line long: flowers tomentose, greenish white, $\frac{2}{3}$ of a line long, the oblong-obovate lobes of the perianth nearly equal. — In the Cantillas Mountains ("Tantillas" of Palmer), Lower California; collected by C. R. Orcutt, August, 1883: the specimens scarcely 6 inches high.

Eriogonum (Oregonium) foliosum. Of the *E. vimineum* group: annual, branching from the base, floccose-tomentose, the branches sparse and spreading: leaves ovate, cordate or cuneate at base, obtuse or acute, undulate, tomentose beneath, 3 to 9 lines long besides the petiole, radical, and in the axils of the subulate bracts: involucres broadly turbinate, cleft nearly to the middle, green, a line long: flowers

half a line long, the segments white or pinkish with a green midvein. — In the Cantillas Mountains, Lower California, by Dr. E. Palmer (n. 348 of 1875, distributed as *E. gracile*, var.?), and in the same region by C. R. Orcutt in 1882, and again in 1883. Differing from tomentose forms of *E. Baileyi* in its stouter leafy and less diffusely branched habit, more ovate undulate leaves, broader involucres, etc.

Aristolochia (Einomeia) subclausa. Stems low and slender (10 to 15 inches high), numerous from an elongated thickened root, sulcate, nearly glabrous: leaves cordate-ovate with a broad sinus, obtuse or acutish, 3-nerved, short-pubescent, about an inch long, the slender petiole 4 lines long: flowers axillary, solitary, upon a short pedicel (2 to 4 lines long), with a sessile ovate bract (3 lines long) at the base of the pubescent 5-sulcate linear ovary (3 or 4 lines long): calyx pubescent, 1 to 1½ inches long, nearly straight or subfalcate, the narrow lamina continuous with the tube (each 6 to 8 lines long), and the somewhat dilated base of the tube partially closed at the throat by a firm smooth reflexed circular diaphragm: stamens 5. — Collected at Tarandacuao in the State of Guanajuato, Mexico; received from Professor A. Dugès, August, 1884. The root, which has about the thickness of a finger, is used as a specific against cholera.

Euphorbia (Anisophyllum) Rattani. Annual, prostrate, pubescent throughout: leaves obliquely ovate, cordate at base, acutish, entire, very shortly petiolate, 2 to 4 lines long: involucres solitary, shortly pedicellate, campanulate, a line long; glands small, equal, rounded and cup-shaped, yellowish, with a narrow white appendage: capsule pubescent, a line long: seed quadrangular, irregularly rugose or nearly smooth. — Found on Stony Creek, Colusa County, California, by V. Rattan, June, 1884. Of the *Chamæsyce* group, and somewhat resembling tomentose forms of *E. polycarpa*, but strictly annual.

TETRACOCCUS, Engelm. Mss.

Flowers diœcious, apetalous. Staminate flowers: sepals 6 or 7, imbricate; stamens as many, in one series, surrounding a central lobulated disk; filaments free, becoming elongated; anthers extrorse, erect, the cells longitudinally dehiscent. Pistillate flowers: sepals 6 or 7, unequal (?); disk 4-lobed (?); ovary 4-celled, the cells 2-ovuled; styles 4, slightly united at base, linear, undivided, spreading. Capsule 4-lobed, the 2-valved cocci separating from a stout 4-angled columella. Seeds strophiolate; albumen fleshy; embryo straight, the cotyledons broad and flat. — A shrub, with mostly opposite entire linear and

nearly nerveless leaves. Flowers small, solitary in the axils, or the axillary peduncles 1–2-flowered.

T. Engelmanni. A much branched shrub, with smooth gray bark, glabrous throughout: leaves mostly opposite or approximately so, sometimes scattered or verticillate in threes, linear, acutish, nerveless excepting the rather obscure midvein, ½ to 1 inch long, on a very short slender petiole: staminate inflorescence shorter than the leaves, the slender small-bracteate peduncles usually 2-flowered, reddish; calyx half a line broad, the slender reddish filaments becoming 2 lines long: pistillate flowers solitary, the stout naked pedicel 3 or 4 lines long in fruit; one or two sepals usually persistent at base of the fruit, 2 lines long: capsule 3 lines in diameter: seeds usually solitary, smooth and shining. — Collected at St. Thomas, Lower California, by Parry, in February, 1883, with immature fruit, and by C. R. Orcutt in September, 1884, with staminate flowers and mature fruit. Specimens from the first collection of this plant were sent to Dr. Engelmann, and probably his last botanical work was in their examination. His notes and sketches have not been accessible to me, but the genus is evidently a new one, of the Euphorbiaceous tribe *Phyllantheæ*, and is not nearly allied to any other of the North American flora.

Acalypha Pringlei. Suffrutescent at base, with elongated slender decumbent branches, glandular-pubescent throughout: leaves broadly ovate, or often cordate with a broad shallow sinus, subcrenately dentate, the blade 9 to 18 lines long, somewhat longer than the petiole: male spikes cylindrical, slender, axillary, with occasionally one or two female flowers on the peduncle, or very rarely at the apex; female spikes terminal and axillary, short and few-flowered and shortly pedunculate: bracts 1-flowered, reniform, with 7 to 11 nearly equal short acutish teeth: stigmas 2 lines long, pinnately divided. — Northern Sonora, C. G. Pringle, 1884. It much resembles 34 Schaffner (*A. vagans*, var. *glandulosa*, Muell.), and 824 of Parry & Palmer (*A. mollis*, HBK., fide Hemsley, but not according to the characters given to that species), both from near San Luis Potosi, and both numbers including two perhaps distinct forms. Their more evident differences from the present species are found in the ovate-cordate leaves with a very narrow sinus, the conspicuously gland-tipped hairs of the pubescence, and the fewer teeth of the bracts. Other differences are found in the flowers, etc. A straggling shrub, 2 or 3 feet high, found on the shore of the Gulf of California, 150 miles south of the boundary.

Croton Pringlei. A woody perennial, 3 to 6 feet high, with slender branches canescent when young; pubescence stellate: leaves

thin, pinnately nerved, nearly glabrous above, somewhat pubescent beneath, especially on the nerves, ovate to oblong-ovate, acuminate or acute, an inch or two long including the short slender petiole, or sometimes smaller, not glandular at base; stipules obsolete: racemes terminal, unisexual, few-flowered: calyx nearly glabrous, of the pistillate flower narrow and spreading: stamens about 15: styles bifid, slender: capsule finely pubescent, subglobose: seed smooth, glabrous, nearly 3 lines long. — Northwestern Sonora, in a low range of hills about thirty miles from the coast; C. G. Pringle, 1884. Allied to *C. Cortesianus*, Kunth.

SEBASTIANIA (?) BILOCULARIS. A monœcious shrub, with light gray bark, glabrous: leaves alternate, linear-oblong or narrowly lanceolate, 1 or 2 inches long, obtuse or acute or acuminate, abruptly contracted at base into a very short petiole, obscurely glandular-toothed, often biglandular at base: inflorescence terminal, the staminate spikes (9 to 12 lines long) bearing a single pistillate flower at base: staminate flowers 4 or 5 together in the naked scattered bracts, the thin calyx 3-parted; stamens 2: ovary 2-celled, with two stout exserted revolute stigmas; capsule smooth, thin-crustaceous, broadly ovate, acute, bicoccous, about 5 lines long, the 2-valved cocci separating from a thin flat 2-nerved imperfect columella: seed subglobose, estrophiolate, 3 lines broad. — In dry water-courses on the hills and mountains of Northwestern Sonora; on hills between Rayon and Ures, Dr. G. Thurber, 1853 (*Sapium salicifolium*, Torr., Bot. Mex. Bound. 201, not HBK.); C. G. Pringle, 1884. Described as 10 to 20 feet high, with upright slender branches; called "Yerba de fleche" by the Papago Indians, who say that the Apaches used to poison their arrows with its milky juice. Aside from the bilocular ovary, the estrophiolate seed, and the peculiar columella, its characters accord with those of the genus as defined by Bentham & Hooker.

HECHTIA TEXENSIS. Diœcious: leaves 18 inches long or less, 1½ to 2 inches broad at base, white-scurfy beneath, glabrous above, with 10 to 12 large distant variously curved teeth on each margin: fertile flowering stem 2 to 4 feet high, bearing a simple pubescent panicle 2 feet long, the branches ascending: flowers solitary and sessile along the branches, subtended by a broadly deltoid-ovate scarious brownish bract: sepals broadly ovate, acute, 2 lines long, brownish and nerved; petals white, 4 lines long, oblong-obovate, nerved: stamens none: ovary and stigmas pubescent: capsule glabrate, 5 lines long: staminate inflorescence unknown. — On limestone bluffs in the Great Bend of the Rio Grande, W. Texas; Dr. V. Havard, August, 1883. The species of

this hitherto only Mexican genus are not very well known, but judging from the figures and descriptions that are given of them this is clearly distinct, as it certainly is from the San Luis Potosi specimens of Schaffner and of Parry & Palmer, referred perhaps erroneously to *H. glomerata*, Zucc.

Tigridia Dugesii. Culm about 10 inches high, shorter than the leaves, from an edible reddish-black bulb: flowers golden yellow, the divisions dotted near the base with reddish purple; sepals oblong-ovate, nearly an inch long; petals hastate-lanceolate, acuminate, half as long, very shortly unguiculate: stamineal column stout: filiform segments of the 2-cleft stigmas as long as the anthers (2 lines long): fruit oblong, 4 lines long. — Described from careful drawings and notes received from Professor A. Dugés of Guanajuato, Mexico, where it is known as "Jahuique de Tupátaro."

Iris bracteata. Rootstock slender: radical leaves solitary, rigid, much exceeding the stem (1 to 2 feet long), striate, one side green, the other glaucous, revolute on drying: stem nearly a foot high, covered with imbricated sheathing bracts 2 to 4 inches long: bracts of the spathe approximate, 2 or 3 inches long, 2-flowered: perianth yellow, with a short funnelform tube; sepals oblong, naked, 2 or 3 inches long, the oblanceolate petals somewhat shorter: capsules on exserted pedicels, ovate-oblong, an inch long. — Collected near Waldo, Josephine County, Oregon, by Thomas Howell, June, 1884. A remarkable species in its foliage. The leaf is unique in character, strictly though obscurely equitant at base, the blade vertical, but the two sides very different, — one side having numerous stomata and an exceedingly thin cuticle, very much as in some revolute-leaved grasses.

Gelasine Texana, Herbert? (*Calydorea Texana*, Baker.) Stem 6 or 8 inches high, with one or two very narrow scarious-sheathing leaves, the terminal bibracteate spathe $1\frac{1}{2}$ inches long; pedicel solitary, shortly exserted: ovary narrowly oblong, 3 lines long, narrower below: perianth purple, the outer segments oblanceolate, an inch long, the inner obovate, 3 lines long, about equalling the filaments, which are united nearly to the top; anthers 4 lines long: style equalling the stamineal tube, the linear stigmas as long. — In damp prairies at San Antonio, Texas; Dr. V. Havard, April, 1884. This is probably the plant upon which Herbert founded his species, which is known only from his description and from Drummond's specimens (n. 415 of his third collection) upon which it was based. These specimens in the Gray herbarium, however, belong wholly to *Nemastylis geminiflora*, Nutt., with the exception of a single separate imperfect flower. The charac-

ters of this are very obscure, though the filaments (said by Herbert to be free) are evidently coherent, as they are in the present plant. It is pretty evident that Herbert's specimens were in the same way a mixture, and that his characters for the species were largely drawn from the *Nemastylis*. The present species is a true *Gelasine*, and not a *Calydorea*, to which genus Herbert's species is referred by Baker, and by Bentham & Hooker.

BLOOMERIA CLEVELANDI. Differing from *B. aurea* in the several very narrow leaves (a line wide or less), in the stouter scape (3 to 7 inches high), in having the thick and fleshy appendage at the base of the filament smooth instead of papillose, and obtuse at the summit instead of bicuspidate, and in the much shorter style, which is shorter than the ovary. — On the mesas near San Diego, California; first collected by D. Cleveland in 1874, and recently received from him and from C. R. Orcutt. *B. aurea* is usually taller and stouter, and with a single much broader leaf (3 to 8 lines wide).

BRODIÆA (SEUBERTIA) LEMMONÆ. Near *B. crocea*, the somewhat scabrous scape a foot high: pedicels less than an inch long: perianth deep orange, 4 to 5 lines long, the segments twice longer than the turbinate tube: filaments in one row at the mouth of the tube, rather stout, terete, nearly equal; anthers 1 to $1\frac{1}{2}$ lines long: ovary very shortly stipitate, beaked, the cells 3–4-ovuled. — Collected on Oak Creek, near Flagstaff, Arizona, by Mr. and Mrs. J. G. Lemmon, August, 1884.

CAMASSIA ESCULENTA, Lindl. Flowers irregular, the outer or lower segment deflexed, the rest with the stamens and style ascending; segments 3- (sometimes 5-) nerved, narrowed and channelled at base, not connivent after opening, but persistent about the base of the capsule: capsule ovate to oblong, obtuse (6 to 9 lines long), equalling or exceeding the usually short pedicel, transversely veined: seeds shining, oblong-obovate. — Ranging from British Columbia to Northern California and eastward to Western Montana and the Wahsatch, often very abundant.

CAMASSIA LEICHTLINII. (*Ornithogalum Leichtlinii*, Baker. *C. esculenta*, var. *Leichtlinii*, Baker, Bot. Mag. t. 6287.) Flowers very nearly regular, the stamens and style ascending, the segments broader and flattened at base, usually 5–7-nerved, connivent and somewhat twisted after opening and at length deciduous: capsule oblong-obovate, slightly emarginate at the apex, usually 8 to 10 lines long and shorter than the pedicels, obliquely veined: seeds obovate, dull. — In Klickitat County, Washington Territory (Suksdorf); at the base of Mount Hood, Ore-

gon (Howell); in the Sierra Nevada, Yosemite Valley, etc. (Bridges, Torrey, Gray), and at Punta de los Reyes, Marin County, California (Bigelow). Mr. Suksdorf, as well as the Messrs. Howell, called attention in 1880 to the distinct characters of this species, and the more recent full and careful notes and abundant specimens of Mr. Suksdorf, upon which the above descriptions are based, confirm their opinion. The plant described and figured by Mr. Baker, as cited, appears to be essentially the same. White flowers are not very unusual in *C. esculenta*, and may be expected in this species also, as he represents them. Mr. Suksdorf notes respecting it that the flowers are usually larger and deeper colored than in *C. esculenta*, the stem stouter but less tall, the leaves mostly broader, often flat and spreading, and glaucous above.

HASTINGSIA BRACTEOSA. Bulb an inch in diameter: leaves elongated, 1 to 1½ feet long or more by 1 to 3 lines wide: scape about two feet high; bracts of the very sparingly branched panicle filiform-attenuate, nearly equalling the flowers, which are 4 lines long on very short pedicels: petals white, linear-lanceolate, twice longer than the stamens; filaments inserted above their base: style stout, nearly as long as the ovary and equalling the stamens. — On "Eigh Dollar Mountain," Curry County, Oregon, by Thomas Howell, May, 1884, with *Darlingtonia* and *Cypripedium Californicum*. This second species confirms in every way the distinctive characters of the genus, and is distinguished from *H. alba* especially by its comparatively longer leaves, more conspicuous bracts, twice larger flowers, and shorter stamens. *H. alba* was also collected by Mr. Howell on hillsides near Kerbyville, Oregon, with mature fruit, which is broadly ovate, nearly 3 lines long, very shortly stipitate, the oblong seeds 2 lines long, with black shining testa.

LILIUM BOLANDERI. Bulb ovate, of numerous lanceolate scales 1 to 1½ inches long: stems ½ to 3 feet high, 1–2-flowered: leaves mostly verticillate and approximate, oblanceolate, acute, glaucous beneath, 1 to 2½ inches long: flowers horizontal or somewhat nodding, "dingy purple" (Rattan) or "dark brownish red" (Howell), becoming somewhat paler, spotted, the segments 1¼ to 1¾ inches long, but slightly spreading, rarely at all recurved: anthers 2 or 3 lines long, the ovary and style 9 or 10 lines long. — In the Red Hills, Humboldt County, California, by Bolander (n. 6558, in part) in 1867; near Arcata, on Humboldt Bay, California, by Volney Rattan in 1878, and on the summit between Illinois and Smith Rivers, near the State boundary, in 1879; and in the same region by Thomas Howell, June, 1884. A well-marked species, allied to *L. parvum* and *L. maritimum*.

TRILLIUM RIVALE. Stems slender, 2 to 8 inches high: leaves lanceolate, rounded or subcordate at base, acute or acuminate, 1 or 2 inches long, on petioles 1 to 15 lines long: pedicel slender, suberect or at length declinate, a little shorter than the leaves: petals subrhombic, acute or acuminate, 6 to 12 lines long, white or more or less marked with purple: stamens exceeding the short stigmas, the filaments adnate to the ovary at base, about equalling the anthers: ovary attenuate above; capsule globose, slightly if at all angled, nearly a half-inch in diameter, beaked by the short style. — On stream-banks in the Siskiyou Mountains, California, and Coast Ranges of Southwestern Oregon. Collected in 1880 by W. H. Shockley at Big Flat, thirty miles east of Crescent City, and by Thomas Howell in June, 1884. It is allied to the eastern *T. nivale*, which it much resembles in habit.

PICEA BREWERIANA. Branches slender, often elongated and pendent, puberulent: leaves 5 to 12 lines long, ½ to nearly one line wide, strictly sessile upon the slender base, obtuse, smooth and rounded or slightly carinate above, stomatose beneath on each side of the slightly prominent midnerve: cones 3 inches long, narrowly cylindrical, attenuate at base; bracts linear-oblong (2 lines long), a fourth of the length of the puberulent scale, which is obovate with the rounded thickish summit entire: seed 1½ lines long, the wing 4 lines long by 2½ broad. — This unusually distinct species has been found (by Thomas Howell, in June, 1884) only at high elevations in the Siskiyou Mountains, California, on the head-waters of the Illinois River, in rather dry rocky ground. It grows to a height of from 100 to 150 feet, and a diameter of 1 to 3 feet. Bark reddish. The specific name is given in compliment to Prof. W. H. Brewer, who in connection with the California State Geological Survey had so much to do with the botany of the State, both in the field and in the after disposal of the collections of the Survey. As he took especial interest in the trees of the coast, and collected a large amount of material for their study, it is fitting thus to connect his name with the forest trees of California.

XV.

AN EXAMINATION OF THE STANDARDS OF LENGTH CONSTRUCTED BY THE SOCIÉTÉ GÉNEVOISE.

BY PROFESSOR W. A. ROGERS.

Communicated December 10th, 1884.

SEVERAL physical laboratories in this country have recently received from the Société Génevoise instruments of precision of various kinds, which appear to have decided merit, both in regard to design and workmanship. The Society has among other things undertaken the construction of standards of length, and of a cathetometer, which is designed to take a high rank as an instrument of precision. Through the kindness of Professor Wright of Yale College, the writer has been permitted the opportunity of a somewhat extended study of one of the standard meters of the Society. Through the courtesy of J. W. Queen & Co. of Philadelphia, the opportunity was at the same time offered of an examination of three other standard meters, and of the meter graduated upon the upright bar of a cathetometer.

On account of the somewhat extended introduction of these standards, it has seemed to the writer worth while to place upon record the results of this examination.

EXAMINATION OF METERS.

The meter belonging to Professor Wright is designated W. The meter of similar form and dimensions received from J. W. Queen & Co. is designated Q_1. A second meter, in which the graduations are nearly along the centre of gravity of a cross section of the bar, is designated Q_2. The graduations upon W, Q_1, and Q_2 are upon silver inlaid in the brass, which is the material of the bars. A third meter, designated Q_3, has the graduations upon the brass. The meter of the cathetometer is designated Q_4.

COMPARISON OF METER W WITH BRONZE STANDARD METER $R_2^{a^2}$ AND STEEL STANDARD METER R_3,

in which, designating the Mètre des Archives by A_0,

$$R_2^{a^2} - 1.6\,\mu = A_0$$
$$R_3 \;\; - 1.2\,\mu = A_0$$

The coefficient of expansion of R_2 for 1° C. in 1 metre is assumed to be 17.17 μ.* The coefficient of R_3 for 1° C. is assumed to be 10.28 μ. At 0° C. these relations become, with these coefficients,

$$R_2^{a^2} + 284.6\,\mu = A_0$$
$$R_3 \;\; + 170.2\,\mu = A_0$$

The values $R_2 - W$ and $R_3 - W$ are given in divisions of the micrometer of the microscope employed, in which

$$1 \text{ div.} = 0.503\,\mu.$$

The thermometer employed is No. 8612 Baudin, and the readings τ have been reduced to the Yale standard.

The observations extend from November 15 to December 3, 1884.

EQUATIONS OF CONDITION BETWEEN R_2 AND W.

No. Obs.	$R_2 - W$		$(16°.67 - \tau)$	$R_2 - W$ at 16°.67	Residuals.	
3	—490.6 div.	$= a$	$+19.41\,b$	—526.1 div.	—3.2 div.	$= -1.6\,\mu$
3	—496.9	$= a$	$+14.79\,b$	—524.0	—1.1	$= -0.6$
3	—499.2	$= a$	$+13.44\,b$	—523.8	—0.9	$= -0.5$
6	—501.0	$= a$	$+10.94\,b$	—521.0	+1.9	$= +1.0$
2	—508.4	$= a$	$+\ 8.07\,b$	—523.2	—0.3	$= -0.2$
4	—512.2	$= a$	$+\ 5.31\,b$	—521.7	+1.2	$= +0.6$
5	—513.3	$= a$	$+\ 1.68\,b$	—516.4	+6.5	$= +3.3$
4	—552.5	$= a$	$-14.06\,b$	—526.8	—3.9	$= -2.0$
			Mean	—522.9		

Normal Equations.

$$-\ 4073.9 = 8\,a + 59.58\,b$$
$$-28977.3 = 59.58\,a + 1189.62\,b$$

Whence

$$a = -522.9 \text{ div.} = -263.0\ \mu$$
$$b = +\ 1.83 \text{ div.} = +\ 0.92\,\mu$$

* Proceedings of the American Academy, Vol. XVIII. p. 341.

EQUATIONS BETWEEN R_3 AND W.

No. Obs.	$R_3 - W$		$R_3 - W$ at 16°.67	Residuals.	
3	−220.4 div.	$= a + 19.41\,b$	−522.0 div.	+2.1 div.	$= +1.1\,\mu$
4	−301.4	$= a + 14.79\,b$	−531.2	−7.1	$= -3.6$
3	−313.7	$= a + 13.44\,b$	−522.6	+1.5	$= +0.8$
6	−351.2	$= a + 10.94\,b$	−521.2	+2.9	$= +1.5$
2	−397.1	$= a + 8.07\,b$	−522.5	+1.6	$= +0.4$
4	−439.1	$= a + 5.31\,b$	−521.6	+2.5	$= +1.3$
5	−501.5	$= a + 1.68\,b$	−527.6	−3.5	$= -1.8$
4	−742.3	$= a - 14.06\,b$	−523.8	+0.3	$= +0.2$
		Mean	−524.1		

Normal Equations.

$$-3266.7 = 8\,a + 59.58\,b$$
$$-12736.4 = 59.58\,a + 1189.62\,b$$

Whence

$$a = -524.1 \text{ div.} = 263.6\ \mu$$
$$b = +\ 15.54 \text{ div.} = 7.82\,\mu$$

It appears from these observations, that the coefficient of W for 1° C. from comparison with R_2 is

$$17.17\,\mu + 0.92\,\mu = 18.09\,\mu;$$

and that the coefficient of W for 1° C. from comparison with R_3 is

$$10.28\,\mu + 7.82\,\mu = 18.10\,\mu.$$

On account of the large deviation from the value communicated by the Society, viz. 19.155 μ, a series of comparisons was instituted beween W and a steel end-meter S immersed in melting ice, according to the method described in the Proceedings of the American Academy, Vol. XVIII. p. 341.

EQUATIONS OF CONDITION BETWEEN W AND S IN MELTING ICE.

No. Obs.	$S - W$	$(16°.67 - \tau)$	$S - W$ at 16°.67	Residuals.	
5	+ 30.0 div.	$= a + 17.75\,b$	−619.1 div.	−0.8 div.	$= -0.4\,\mu$
5	− 7.5	$= a + 16.66\,b$	−616.8	+1.5	$= +0.8$
10	− 177.0	$= a + 12.24\,b$	−624.6	−6.3	$= -3.2$
9	− 198.3	$= a + 11.58\,b$	−621.8	−3.5	$= -1.8$
5	− 260.9	$= a + 9.58\,b$	−611.2	+7.1	$= +3.6$
6	− 327.4	$= a + 7.94\,b$	−617.8	+0.5	$= +0.3$
4	− 369.8	$= a + 6.73\,b$	−615.9	+2.4	$= +1.2$
10	− 571.5	$= a + 1.28\,b$	−618.3	+0.0	$= +0.0$
18	−1124.7	$= a - 13.83\,b$	−618.9	−0.6	$= -0.3$
		Mean	−618.3		

Normal Equations.

$$-3007.1 = 9a + 69.93b$$
$$+3180.1 = 69.93a + 1269.56b$$

Whence

$$b = 36.57 = 18.39\,\mu$$

Combining this value with the values $18.09\,\mu$ derived from R_2, and $18.10\,\mu$ derived from R_3, we have:

Coefficient of expansion of bar W in one meter $= 18.19\,\mu$ for each degree Centigrade.

For the relation between W and A_0 at 16°.67 C. = 62°.0 Fahr., we have:

$$W - 263.0\,\mu = R_2 = A_0 + 1.6\,\mu \qquad W - 263.6\,\mu = R_3 = A_0 + 1.2\,\mu$$
$$W - 264.6\,\mu = A_0 \qquad W - 264.8\,\mu = A_0$$

And finally, $$W - 264.7\,\mu = A_0$$

Reducing to 0° C., with the coefficient $18.19\,\mu$, we have at 0°

$$W + 38.5\,\mu = A_0$$

A slightly different but probably more accurate value of this relation will be obtained by selecting only those comparisons which were made near 0°. From these data we have:

No. Obs.	8612 °	$R_2 - W$	$R_2 - W$ at 0° C.	No. Obs.	8612 °	$R_3 - W$	$R_3 - W$ at 0° C.
3	−2.74	−490.6 div.	−249.6 μ	3	−2.74	−220.4 div.	−132.6 μ
3	+1.88	−496.9	−247.9	4	+1.88	−301.4	−136.9
3	+3.43	−499.2	−247.6	3	+3.00	−313.7	−132.4
6	+5.73	−501.0	−246.2	6	+5.73	−351.2	−132.2
		Mean	−247.8				−133.5

Whence $$W + 36.1\,\mu = A_0 \qquad W + 36.0\,\mu = A_0$$

COMPARISON OF STANDARD Q_1 WITH STANDARDS R_2 AND R_3.

EQUATIONS OF CONDITION BETWEEN R_2 AND Q_1.

No. Obs.	$R_2 - Q_1$		$R_2 - Q_1$ at 16°.67	Residuals.	
6	−580.2 div.	$= a + 16.02b$	−604.9 div.	+1.0 div.	= +0.5 μ
4	−586.9	$= a + 12.54b$	−606.2	−0.3	= −0.2
2	−597.1	$= a + 6.59b$	−607.2	−1.3	= −0.6
4	−627.1	$= a - 14.06b$	−605.4	+0.5	= +0.3
		Mean	−605.9		

Normal Equations.

$$-2391.30 = 4a + 21.09b$$
$$-11772.39 = 21.09a + 655.00b$$

Hence

$$a = -605.9 = 304.8\ \mu$$
$$b = +\ 1.54 = 0.78\mu$$

$$Q_1 - 304.8\mu = R_2 = A_0 + 1.6\mu$$
$$Q_1 - 306.4\mu = A_0$$

$$\text{Coefficient} = 17.17\mu + 0.78\mu = 17.95\mu$$

EQUATIONS OF CONDITION BETWEEN Q_1 AND R_3.

No. Obs.	$R_3 - Q_1$		$R_3 - Q_1$ at 16°.67	Residuals.	
6	−364.2 div.	$= a + 16.02b$	−603.4 div.	+3.3 div.	= +1.7 μ
4	−424.2	$= a + 12.54b$	−611.4	−4.7	= −2.4
2	−506.9	$= a + 6.59b$	−605.4	+1.3	= +0.7
4	−816.5	$= a - 14.06b$	−606.6	+0.1	= +0.1

Normal Equations.

$$-2111.8 = 4a + 21.09b$$
$$-3014.4 = 21.09a + 655.00b$$

Hence

$$a = -606.7 = -305.2\ \mu$$
$$b = +\ 14.93 = +\ 7.51\mu$$

$$Q_1 - 305.2\mu = R_3 = A_0 + 1.2\mu$$
$$Q_1 - 306.4\mu = A_0$$

$$\text{Coefficient} = 10.28\mu + 7.51\mu = 17.79\mu$$

COMPARISON BETWEEN STANDARDS Q_2, R_2, AND R_3.

EQUATIONS OF CONDITION BETWEEN R_2 AND Q_2.

No. Obs.	$R_2 - Q_2$		$R_2 - Q_2$ at 16°67	Residuals	
6	−530.8 div.	$= a + 16.03b$	−574.5 div.	−3.8 div.	= −1.9 μ
4	−533.9	$= a + 12.96b$	−569.2	+1.5	= +0.8
3	−539.1	$= a + 10.40b$	−567.5	+3.2	= +1.6
4	−609.9	$= a - 14.06b$	−571.5	−0.8	= −0.4

Normal Equations.

$$-2213.7 = 4a + 25.33b$$
$$-12459.4 = 25.33a + 730.76b$$

Hence

$$a = -570.7 = -287.1\ \mu$$
$$b = +\ 2.73 = +\ 1.45\mu$$

$$Q_2 - 287.1\mu = R_2 = A_0 + 1.6\mu$$
$$Q_2 - 288.7\mu = A_0$$

$$\text{Coefficient} = 17.17\mu + 1.45\mu = 18.62\mu$$

Equations of Condition between Q_2 and R_3.

No. Obs.	$R_3 - Q_2$		$R_3 - Q_2$ at 16°.67	Residuals.		
6	—324.4 div.	$= a + 16.03\,b$	—579.4 div.	—5.5 div.	=	$-2.8\,\mu$
4	—361.6	$= a + 12.96\,b$	—567.7	+6.2	=	+3.1
3	—408.3	$= a + 10.40\,b$	—573.8	+0.1	=	+0.1
4	-798.3	$= a - 14.06\,b$	—574.6	—0.7	=	—0.4

Normal Equations.

$$-1892.6 = 4a + 25.33\,b$$
$$-2908.6 = 25.33\,a + 730.76\,b$$

Hence

$$a = -573.8 \text{ div.} = 288.6\ \mu$$
$$b = +\ 15.91 \text{ div.} = 8.00\,\mu$$

$$Q_2 - 288.6\,\mu = R_3 = A_0 + 1.9\,\mu$$
$$Q_2 - 289.8\,\mu = A_0$$

$$\text{Coefficient} = 10.28\,\mu + 8.00\,\mu = 18.28\,\mu$$

Comparison of Q_3 with R_2.

	8612 °	$R_2 - Q_3$
	+2.12	—600.7 div.
	+2.23	—580.2
	+3.22	—586.9
	+4.70	—579.6
	+3.60	—576.2
Means	+3.17	—584.7

Reduced to 0° with coeff. 1.83 div., we have

$$R_2 - Q_3 \text{ at } 0^\circ = -579.2 = -301.3\,\mu$$

Hence

$$Q_3 - 301.3\,\mu = R_2 = A_0 - 284.6\,\mu$$
$$Q_3 -\ 16.7\,\mu = A_0$$

COMPARISON OF CATHETOMETER METER Q_4 WITH R_2 AND R_3.

Equations of Condition between Q_4 and R_2.

No. Obs.	$R_2 - Q_4$		$R_2 - Q_4$ at 16°.67	Residuals.		
7	—644.1 div.	$= a + 16.19\,b$	—631.0 div.	—0.6 div.	=	$-0.3\,\mu$
7	—637.5	$= a + 12.69\,b$	—627.2	+3.2	=	+1.6
7	—638.4	$= a + 10.68\,b$	—629.7	+0.7	=	+0.4
3	—639.4	$= a + 6.24\,b$	—634.3	—3.9	=	—2.0
8	—618.9	$= a - 13.24\,b$	—629.6	+0.8	=	+0.4

Normal Equations.

$$-\ 3178.3 \text{ div.} = 5a + 32.56\,b$$
$$-21131.7 \text{ div.} = 32.56\,a + 751.46\,b$$

Hence

$$a = -630.4 = 317.1\ \mu$$
$$b = -\ 0.81 = 0.41\,\mu$$

$$Q_4 - 317.1\,\mu = R_2 = A_0 + 1.6\,\mu$$
$$Q_4 - 318.7\,\mu = A_0$$

$$\text{Coefficient} = +17.17\,\mu - 0.41\,\mu = 16.76\,\mu$$

EQUATIONS OF CONDITION BETWEEN Q_4 AND R_3.

No. Obs.	$R_3 - Q_4$		$R_3 - Q_4$ at 16°.67	Residuals.	
7	—423.2 div.	$= a + 16.19\,b$	—625.6 div.	+2.8 div.	= +1.4 μ
4	—472.2	$= a + 12.63\,b$	—630.1	—1.7	= —0.9
3	—552.1	$= a + 6.24\,b$	—630.1	—1.7	= —0.9
4	—800.2	$= a - 13.81\,b$	—627.6	+0.8	= +0.4

Normal Equations.

$$-2247.7 = 4\,a + 21.25\,b$$
$$-5209.8 = 21.25\,a + 651.30\,b$$

Hence

$$a = -628.4 = -316.1\ \mu$$
$$b = +\ 12.50 = +\ 6.29\,\mu$$

$$Q_4 - 316.1\,\mu = R_3 = A_0 + 1.2\,\mu$$
$$Q_4 - 317.3\,\mu = A_0$$

$$\text{Coefficient} = +10.28\,\mu + 6.29\,\mu = +16.57\,\mu$$

For the mean value we have:

$$Q_4 - 318.0\,\mu = A_0$$
$$\text{Coefficient} = 16.66\,\mu$$

For the relations between Q_1, Q_2, Q_4, and A_0, at 0° C., we have, from the comparisons made near 0°, as follows:

8612 Reading at Observation.	$R_2 - Q_1$ at 0°	$R_3 - Q_1$ at 0°	8612 Reading at Observation.	$R_2 - Q_2$ at 0°	$R_3 - Q_2$ at 0°
° + 0.65	—291.3 μ	—178.3 μ	° +0.64	—266.2 μ	—158.0 μ
+ 4.13	—292.3	—182.2	+3.71	—263.7	—151.7
+10.08	—293.1	—178.9	+6.27	—283.0	—154.6
Means	—292.2	—179.8		—264.3	—154.8

$$Q_1 - 292.2\,\mu = R_2 \qquad Q_1 - 179.8\,\mu = R_3$$
$$= A_0 - 284.6\,\mu \qquad = A_0 - 170.2\,\mu$$
$$Q_1 -\ 7.6\,\mu = A_0 \qquad Q_1 -\ 9.6\,\mu = A_0$$

For the mean $Q_1 - 8\ 6\,\mu = A_0$

$$Q_2 - 264.3\,\mu = R_2 = A_0 - 284.6\,\mu \qquad Q_2 - 154.8\,\mu = R_3 = A_0 - 170.2\,\mu$$

$$Q_2 + 20.3\,\mu = A_0 \qquad Q_2 + 15.4\,\mu = A_0$$

For the mean $Q_2 + 17.8\,\mu = A_0$

8612 Reading at Observation.	$R_2 - Q_4$ at 0°	8612 Reading at Observation.	$R_3 - Q_4$ at 0°
°		°	
+ 0.48	$-324.2\,\mu$	+ 0.48	$-209.8\,\mu$
+ 3.98	-322.6	+ 3.98	-212.2
+ 5.94	-324.0	+10.43	-211.4
+10.63	-326.7		
Means	-324.4		-211.1

$$Q_4 - 324.4\,\mu = R_2 = A_0 - 284.6\,\mu \qquad Q_4 - 211.1\,\mu = R_3 = A_0 - 170.2\,\mu$$

$$Q_4 - 39.8\,\mu = A_0 \qquad Q_4 - 40.9\,\mu = A_0$$

For the mean $Q_4 - 40.3\,\mu = A_0$

Collecting results, we have:

At 0°	At 16°.67	Coefficient.
$W + 36.1\,\mu = A_0$	$W - 264.7\,\mu = A_0$	$18.19\,\mu$
$Q_1 - 8.6 = A_0$	$Q_1 - 306.4 = A_0$	17.87
$Q_2 + 17.8 = A_0$	$Q_2 - 289.2 = A_0$	18.45
$Q_3 - 16.7 = A_0$	. . . . .	. . .
$Q_4 - 40.3 = A_0$	$Q_4 - 318.0 = A_0$	16.71

It will be seen that every value of the coefficient is less than the value communicated by the Society, viz. $19.155\,\mu$. It seems impossible to resist the evidence given by this determination, that this value is certainly too large. It is possible that the solution of the discrepancy may be found in the fact shown by these observations, that when the graduations are upon silver inlaid in brass, the coefficient of the brass controls that of the silver somewhat in proportion to the relative masses of the two metals. In every one of the five cathetometers standardized by the writer, the brass has carried the silver with it, that is, the coefficient has been found to be that of brass, and not that of silver.

It will be seen that the cathetometer has a less coefficient than the bronze bar R_2, which is identical in composition with the Imperial Yard.

It is probable, also, that the resultant coefficient of two metals which have a mechanical junction depends somewhat upon the perfection with which the junction is made. The writer has not found so large differences as here given in the values of the coefficient for different specimens of the same metal, but in this case the differences may be

due to accidental errors of observation, on account of the limited number of comparisons made.

It should be stated also, that, judging by the color of the metal, the composition of W and Q_1 differs from that of Q_2 and Q_4.

It now only remains to describe some observations which were made to determine the extent to which the variations in the length of the standards under variations of temperature correspond with the computed values from the indicated readings of the thermometer when placed upon the upper surface of the bars.

First, a series of comparisons were made with a rising temperature. When reduced to 16°.67, the value of $R_2 - W$ should be 522.9 div. The following are the observed values.

	Time. h m.	8612 °	$R_2 - W$ at 16°.67	Deviation from 522.9 div.		
A. M.	7 10	6.20	—516.5 div.	— 6.4 div.	=	—3.2 μ
"	8 20	7.30	—517.7	— 5.2	=	—2.6
"	9 30	7.92	—522.1	— 0.8	=	—0.4
"	11 20	12.07	—517.1	— 5.8	=	—2.9
"	12 50	13.67	—511.3	—11.6	=	—5.8

It therefore appears that, for a rising temperature of about 1° for each hour of time, the length derived from the reading of the thermometer will be from 2 μ to 3 μ too short.

The length of W was then compared with an end-meter in melting ice with a falling temperature. The temperature of the comparing-room had for several hours remained at 15°.4 C. At 8h. 27m. A. M. both windows were opened. The relation $S - W$ had been previously found to be —618.3 div. The comparisons were now continued every three minutes with the following results.

Time. A. M. h. m.	8612 °	$S - W$ at 16°.67 div.	Deviation from —618 3 div. div.	μ	Time. A. M. h m.	8612 °	$S - W$ at 16° 67 div.	Deviation from —618.3 div. div.	μ
8 30	14.55	—634.2	+15.9	=+ 8.0	8 54	11.97	—631.0	+12.7	=+ 6.4
8 33	14.25	—633.0	+14.7	=+ 7.4	8 57	11.39	—644.7	+26.4	=+13.3
8 36	13.67	—645.6	+27.3	=+13.7	9 0	11.10	—640.2	+21.9	=+11.0
8 39	13.41	—639.8	+21.5	=+10.8	9 3	10.94	—636.0	+17.7	=+ 8.9
8 42	13.07	—639.3	+21.0	=+10.6	9 6	10.95	—623.3	+ 5.0	=+ 2.5
8 45	12.76	—646.1	+27.8	=+14.1	9 9	10.90	—623.5	+ 5.2	=+ 2.6
8 48	12.57	—639.9	+21.6	=+10.9	9 12	11.00	—615.9	— 2.4	=— 1.2
8 51	12.19	—643.1	+24.8	=+12.5					

It appears, therefore, that the measured length will be found to be too great under a rapidly falling temperature by about 10 μ or 12 μ for at least half an hour after the change of temperature has occurred.

Under circumstances similar to those described above, it will not be safe to make the comparisons under about one hour after the change of temperature. For a bronze bar having a cross section of one inch, the writer has found that this limit of time is about five hours. This form of the metres of the Society, therefore, seems to be well adapted for ordinary use. But it should be stated that the small depth of the bars W and Q_1 requires that they shall rest upon a flat surface during comparison, — something not easy to obtain.

In the third test, the temperature of bar W was raised to about 28° C. by heating over a register. At 3h. 19m. P. M. it was removed to the comparing room within which the temperature remained very constant at about 19°.0 C. Comparisons were then made every three or four minutes with the end-meter in melting ice, as follows. The comparisons were begun when the thermometer placed upon the bar ceased to rise.

Time. P. M. h. m.	8612 °	$S-W$ at 16°.67	Deviation from −618.3 div.		Time. P. M. h. m.	8612 °	$S-W$ at 16°.67	Deviation from −618.3 div.	
3 21	12.45	−620 div.	+17 div.	+ 1 μ	3 42	6.40	−647 div.	+29 div.	+15 μ
3 25	8.31	−676	+58	+29	3 44	6.21	−649	+31	+16
3 29	7.32	−676	+58	+29	3 46	6.09	−636	+18	+ 9
3 33	6.85	−667	+49	+25	3 49	6.00	−638	+20	+10
3 36	6.55	−660	+42	+21	3 51	5.77	−638	+20	+10
3 39	6.46	−658	+40	+20	3 54	5.49	−642	+24	+12

It will be noticed from these results, that the bar remained nearly two minutes in the comparing-room before the change of length was decidedly apparent. After that, the computed length was too great by a maximum amount of 29 μ, and notwithstanding the fact that after about fifteen minutes the thermometer readings decreased very slowly and with considerable regularity, the indicated length of the meter was at the expiration of 33 minutes still 12 μ too great. It is apparent, therefore, that, under circumstances similar to those described above, it will not be safe to make comparisons until the bar shall have remained at a nearly constant temperature for at least one hour.

The lines traced upon the silver surface are, in all these standards, of the best quality. The edges are not rounded, and it is possible to focus upon the lines with great sharpness. The writer has never before seen heavy lines of as good quality as these. The width of the lines in W, Q_1, and Q_2 is about 20 μ, and in Q_3 about 50 μ. In Q_4 the width is slightly different at the two ends, the mean value being about 25 μ.

The only serious criticism to be made upon these standards is, that

the surfaces of W and Q_1 are slightly convex between centimeters 15 and 45, while Q_3 is convex to a less degree between centimeters 70 and 85. The surface of Q_4 is nearly plane when the cathetometer is supported at its neutral points.

RELATIVE ERRORS OF THE SUBDIVISIONS.

A plus sign indicates that the measured space is too short.

Decimeters.

Spaces.	W	Σ	Q_1	Σ	Q_3	Σ	Q_4	Σ
1	$+0.7\mu$	$+0.7\mu$	-5.8μ	-5.8μ	$+4.7\mu$	$+4.7\mu$	$+0.0\mu$	$+0.0\mu$
2	+11.3	+12.0	+ 1.9	− 3.9	+ 0.2	+ 4.9	− 2.5	− 2.5
3	+ 6.0	+18.0	−23.0	−26.9	−18.4	−13.5	− 1.1	− 3.6
4	−11.0	+ 7.0	+ 4.0	−22.9	− 0.1	−14.6	− 1.7	− 5.3
5	− 1.6	+ 5.4	+17.7	− 5.2	+ 0.9	−13.7	+ 9.1	+ 3.8
6	+ 3.0	+ 8.4	+ 5.3	+ 0.1	+ 0.2	−13.5	+ 1.4	+ 5.2
7	− 8.7	− 0.3	−11.1	−11.0	− 0.9	−14.4	− 9.3	− 4.1
8	+ 4.6	+ 4.3	−17.7	−28.7	+ 8.5	− 5.9	+ 8.6	+ 4.5
9	+ 1.3	+ 5.6	+11.4	−17.3	+ 4.3	− 1.6	+ 6.3	+10.8
10	− 5.3	+ 0.0	+17.3	+ 0.0	+ 1.6	+ 0.0	−10.8	+ 0.0

The relative errors of the 10 centimeters of the first decimeters of Q_3 and Q_4 were found to be as follows. The centimeter subdivisions of W and Q_1 were not investigated.

Spaces.	Q_3	Σ	Q_4	Σ
1	$+0.5\mu$	$+0.5\mu$	$+1.4\mu$	$+1.4\mu$
2	−5.0	−4.5	−1.1	−0.3
3	−2.8	−7.3	−4.7	−5.0
4	−0.8	−8.1	−4.0	−9.0
5	+1.9	−6.2	+4.1	−4.9
6	+0.3	−5.9	+5.1	+0.2
7	+1.1	−4.8	−3.1	−2.9
8	+3.1	−1.7	+0.4	−2.5
9	+1.3	−0.4	+4.9	+2.4
10	+0.4	+0.0	−2.4	+0.0

The errors of the one-tenth millimeter subdivisions seem to be inappreciable, indicating that the screw employed has no sensible periodic error which is a function of a single revolution.

With regard to the decimeter subdivisions, it should be said that the graduation was done in three operations, the second zero being at about the thirty-third centimeter, and the third at about the sixty-sixth centimeter.

XVI.

A METHOD OF FILTRATION BY MEANS OF EASILY SOLUBLE AND EASILY VOLATILE FILTERS.

By F. A. Gooch.

Communicated March 11, 1885.

The processes of analysis, in which it is desirable to redissolve precipitates from the filter after washing, or to separate a mixed precipitate into parts by the action of appropriate solvents, are many.

When a complete solution is the object, and the precipitate yields easily to solvents which do not affect paper injuriously, the use of the ordinary filter offers no difficulty. When, however, precipitates are to be treated with reagents which disintegrate paper filters, the case is otherwise; and the attempt to remove, by solvents, any individual part of a mixed heterogeneous mass upon a filter, is always an uncertain matter. As examples of cases of this sort, difficult to deal with, we may take the solution of acid sodic titanate in strong hydrochloric acid; or, the purification of baric sulphate from included salts, by digestion in strong hydrochloric acid; or, the separation of sulphides which are soluble from those which are insoluble in alkaline sulphides; or, the washing out of free sulphur from precipitated sulphides by means of carbon disulphide; or, the separation of calcic and baric sulphates by the action of sodium hyposulphite. In cases of this nature it is often convenient to make use of the asbestos filter which I have previously described; * but this sometimes has its disadvantages. Thus, to recur to the examples just cited, acid sodium titanate may be filtered and washed upon an asbestos filter, and felt and precipitate treated together with hydrochloric acid, but it will be impossible to determine when solution is effected because of the floating asbestos; and in separating the sulphides it would be necessary to know the weight of the asbestos felt, since it must be weighed finally with the insoluble sulphides, unless removed by a special treatment which involves the solution, filtration, and reprecipitation of the latter.

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* These Proceedings, Vol. XIII. p. 342.

It is to meet cases like these that I have sought a filter which, in the reversal of the ordinary mode of separating filter and precipitate, should dissolve easily in solvents which do not affect the ordinary precipitates met with in analysis. The material which seems best suited to the case — light and fluffy, capable of making secure filters of any desirable degree of porosity, sufficiently insoluble in water and aqueous solutions of salts, alkalies, and acids (excepting strong sulphuric, strong nitric, and glacial acetic acids), easily soluble in naphtha, benzol, carbon disulphide, ether, boiling alcohol, and essential oils, and not too costly — is anthracene.

The mode of preparing and using the filter is simple. Anthracene is slightly moistened with alcohol to make it miscible with water, diluted to the right consistency, and applied to the same apparatus, and in the same way, as the emulsion of asbestos which is employed in making asbestos felts. That is to say, enough of the emulsion in water to form a layer of the proper thickness is poured into a perforated crucible which is held tightly in a packing of rubber tubing stretched over a funnel fitted in the usual manner to a vacuum-flask or receiver. After washing with water the filter is ready for use. If the felt happens to be too coarse for the use of the moment, it may be made as close as need be by coating the felt first deposited with a finer emulsion, made by dissolving anthracene in hot alcohol and precipitating with water. When voluminous precipitates are to be filtered, the large perforated cone described in the former paper, to which I have referred, may be substituted with advantage for the crucible; or Cooke's improved form * of Carmichael's process of reverse filtration may prove most useful. In using the cone it is well to apply the anthracene in a thick layer.

To remove the anthracene filter from a precipitate, it is only necessary to act with the proper solvent. It is usually convenient to stand the crucible containing precipitate and felt in a small beaker, add enough of the solvent, and gently warm until the anthracene dissolves. On the addition of water, or the reagent to work upon the precipitate, the solution of anthracene floats, and nothing remains to obstruct or obscure the action. If the precipitate dissolves entirely, the solution of anthracene may be separated from the aqueous solution by simply pouring the fluid upon a filter previously moistened with water, when the solution in water runs through, and the anthracene and its solvent remain and may be washed indefinitely with water.

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* These Proceedings, Vol. XII. p. 124.

If, on the other hand, the case is one of the division of precipitates, the anthracene and its solvent may be made to pass the filter, after the water has run through, by adding a little alcohol to overcome the repulsion between the solution and the water which fills the pores of the filter, the precipitate which stays behind being washed first with a solvent of anthracene, and then, if necessary, with alcohol followed by water; or, if the vacuum filter be used (either paper or asbestos, according to the circumstances of the case), both liquids leave the precipitate and traverse the filter together.

In general, I prefer benzol as the solvent for anthracene, but some advantage may be gained in special cases by a proper choice of solvents. Thus, in removing intermixed sulphur from precipitated sulphides, both the anthracene and the sulphur may be dissolved in carbon disulphide in a single operation.

The ready volatility of anthracene, at a temperature very near its melting point, 213° C., makes it easily separable in cases when to remove it by a solvent is not advisable. The treatment of a solution of anthracene, for example, with strong sulphuric or nitric acid, is apt to produce carbonaceous or gummy residues. In such cases it is well either to heat precipitate and filter directly, or to first remove them from the crucible by means of a solvent for anthracene, then evaporate this and raise the heat gently until the anthracene has vanished. The purification of precipitated baric sulphate, by dissolving it in hot, strong sulphuric acid, and reprecipitating by dilution, is a case in point; and one, too, in which the reversed filter may be used with great advantage. It may be remarked, in passing, that, if one does not happen to possess a platinum rose, and does happen to have at disposal a perforated crucible, a very fair reversed filter may be improvised of the crucible, a piece of glass tubing, and a rubber stopper, the last being fitted to the crucible, and the tube passed through nearly to the perforated bottom.

At every point in the preparation and use of the anthracene filter, I have found the manipulation peculiarly easy.

XVII.

OBSERVATIONS OF VARIABLE STARS IN 1884.

BY EDWARD C. PICKERING.

Communicated March 11, 1885.

IN the communication entitled "Recent Observations of Variable Stars,"[1] it was stated that a similar circular would be published early in 1885. The friendly co-operation of several astronomers interested in the subject makes it practicable to present on this occasion a much fuller view of the progress of observation, in Europe as well as in America, than could be given last year. The various observers are named below in alphabetical order, with the abbreviations employed to designate them in the subsequent tabular statements.

B. These observations were made by Mr. T. W. Backhouse, at Sunderland, England. The instruments employed were a refracting telescope by Cooke, aperture $4\frac{1}{4}$ inches, with magnifying powers 38 and 75; the finder of this telescope, power 9; a field-glass and an opera-glass, with powers 4 and 2.2 respectively; other observations were made with the naked eye. The comparisons were made either in grades, in fractions of the interval between two comparison stars, or by approximate differences. A copy of the observations for 1884 has been received at the Harvard College Observatory.

C. These observations were made by Mr. S. C. Chandler, Jr., at the Harvard College Observatory. The telescope is by Clacey; aperture $6\frac{1}{4}$ inches, magnifying power generally 45, sometimes 125 or 200. The observations were made by Argelander's method. Most of them were made before April 28, and they were discontinued after June 30, owing to the requirements of other researches. They are not likely to be resumed at present.

D. These observations were made by Dr. N. C. Dunér, at the Observatory of Lund, Sweden, according to the method of Argelander.

E. These observations were made by Mr. John H. Eadie, at Bayonne, New Jersey. The telescope employed was made by John Byrne; its aperture is $3\frac{1}{4}$ inches, and the lowest magnifying power

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[1] Proc. Amer. Acad. of Arts and Sciences, XIX. 296.

about 50. Argelander's method of comparison is used. A copy of the observations has been furnished to the Harvard College Observatory.

Hg. These observations were made by Dr. E. Hartwig, formerly of Strassburg, Germany, at present of Dorpat, Russia. Since his removal to Dorpat, circumstances have prevented Dr. Hartwig from making frequent observations of variable stars.

Hn. These observations were made by the Rev. J. Hagen, S. J., at the College of the Sacred Heart, Prairie du Chien, Wisconsin. The instrument is a telescope by Merz; its aperture is 3 inches. The observations were made by the division into tenths of the interval between two comparison stars. A copy of the observations has been furnished to the Harvard College Observatory. Messrs. Zwack and Zaiser have taken part in the work as assistants.

K. These observations were made by Mr. George Knott, at Knowles Lodge, Cuckfield, Hayward's Heath, England. The telescope employed was made by Alvan Clark and Sons; its aperture is $7\frac{1}{3}$ inches, and that of the finder 2 inches. The variable is compared with stars differing little from it in brightness; the magnitudes of the comparison stars, and sometimes the magnitude of the variable, are determined by the method of limiting apertures.

P. These observations were made by Mr. H. M. Parkhurst, at Brooklyn, N. Y. The instrument is a telescope made by Fitz; its aperture is 9 inches, and the magnifying powers employed are 56 and 150. Many of the observations were made by Argelander's method, and the remainder with photometric apparatus devised by Mr. Parkhurst, and partially described in the previous circular. A copy of the observations has been furnished to the Harvard College Observatory.

Sk. Professor Safarik of Prague, Austria, has published a notice of his observations of variable stars in the Vierteljahrsschrift der Astronomischen Gesellschaft, XIX. 144, from which the memoranda given in this circular are derived.

Sr. These observations were made according to Argelander's method by Mr. E. F. Sawyer, at Cambridgeport, Massachusetts, by means of an opera-glass for the brighter stars and of a field-glass for the others. The same plan of observation will be followed during 1885.

W. These observations were made by Dr. F. Wilsing, at the Astrophysikalisches Observatorium, Potsdam, Germany. The wedge photometer was employed in part of the comparisons, but in such cases estimates in grades of the difference in brightness between the stars compared were almost always added. These estimates appear to be somewhat more accurate than the photometric observations, which will

therefore be employed in future chiefly in determining the brightness of the comparison stars.

Zk. The observations of Assistant G. Zwack have already been mentioned under the heading Hn.

Zr. The observations of Assistant Zaiser have already been mentioned under the heading Hn.

The summary of the progress of observation during 1884 is contained in the last column of Table I. The preceding columns are repeated, after correcting some numerical errors, from the corresponding table in the statement published last year. The first column of the left-hand page gives a provisional number for designating the star. This number is taken from Schönfeld's Catalogue when the star occurs there; in other cases, a letter is added to the number. Other letters may be employed in effecting additional interpolation. The second column contains numbers from the Photometric Catalogue called Harvard Photometry, and published in Volume XIV. of the Annals of the Harvard College Observatory. The following columns contain the usual designation of the star, its right ascension and declination for 1875, magnitude at maximum and minimum, and period in days.

The first column of the right-hand page repeats the number to be used for the provisional designation of the star. The second gives the class to which the star belongs, upon the system of classification employed in the Proceedings of the American Academy of Arts and Sciences, XVI. 257. Upon this system, Class I. includes temporary stars; Class II., stars undergoing large variations in periods of several months; Class III., irregularly variable stars undergoing but slight changes in brightness; Class IV., variable stars of short period, like *β Lyræ* or *δ Cephei;* Class V., Algol stars, or those which at regular intervals undergo sudden diminutions of light, lasting for but a few hours. The third column gives the name of the discoverer, and the fourth column the date.

The last column, as above stated, contains the number of nights on which each star was observed by the astronomer whose designation is attached to the number. A dash preceding a designation shows that the star has been observed, but that the number of nights has not been furnished. The abbreviations employed have been explained above. The letter K. is preceded by two numbers, the first of which relates to observations made in 1883.

Table I. is followed by a series of remarks containing observed dates of maximum and minimum, and other information received from the observers with regard to particular stars.

TABLE I. — VARIABLE STARS.

No.	H.P.	Name.	R. A. 1875.	Dec. 1875.	Max.	Min.	Per.
			h. m. s.	° ′	m.	m.	d.
0a	—	Ceti	0 15 26	−20 45.1	5.2	7.0	—
1	51	T Cassiopeiæ	16 29	+55 5.9	6.5 — 7.0	11 — 11.2	436
2	54	R Andromedæ	17 28	+37 53.0	5.6 — 8.6	<12.8	404.7
3	—	S Ceti	17 42	−10 1.3	7.0 — 8.0	<10.7	323.6
4	—	B Cassiopeiæ	17 52	+63 27.2	>1	?	—
5	—	T Piscium	25 31	+13 54.6	9.5 — 10.2	10.5 — 11.0	Irr.
6	94	α Cassiopeiæ	33 25	+55 51.1	2.2	2.8	Irr.
6a	—	U Cephei	51 18	+81 12.1	7.0	9.5	2.5
7	—	S Cassiopeiæ	1 10 30	+71 57.2	6.7 — 8.5	<13	615
8	—	S Piscium	11 2	+ 8 16.3	8.8 — 9.3	<13	406.6
8a	—	Piscium	16 22	+12 12.7	10	14	—
8b	—	Ceti	19 31	− 4 36.6	6.5	7.8	—
8c	—	R Sculptoris	21 13	−33 11.5	5¾	7¾	207
9	—	R Piscium	24 12	+ 2 14.1	7.4 — 8.3	<12.5	345
10	—	S Arietis	57 55	+11 55.5	9.1 — 9.8	<13	288.8
11	—	R Arietis	2 9 1	+24 28.4	7.6 — 8.5	11.9 — 12.7	186.2
12	370	ο Ceti	13 1	− 3 32.7	1.7 — 5.0	8 — 9	331.3
13	—	S Persei	13 54	+58 0.8	8.5 ?	<9.7	—
14	—	R Ceti	19 39	− 0 44.6	7.9 — 8.7	<12.8	167.1
15	—	T Arietis	41 22	+16 59.3	7.9 — 8.2	9.4 — 9.7	324
16	489	ρ Persei	57 10	+38 21.3	3.4	4.2	Irr.
17	496	β Persei	3 0 2	+40 28.4	2.2	3.7	2.9
18	—	R Persei	22 6	+35 14.3	8.1 — 9.2	12.5	208.8
19	657	λ Tauri	53 45	+12 8.2	3.4	4.2	4.0
20	—	T Tauri	4 14 43	+19 14.3	9.2 — 11.5	12.8 — <	Irr.
21	—	R Tauri	21 27	+ 9 52.9	7.4 — 9.0	<13	325.6
22	—	S Tauri	22 22	+ 9 40.1	9.9	<13	378
22a	—	Doradus	35 19	−62 19.4	5½	6¾	—
23	—	V Tauri	44 48	+17 19.6	8.3 — 9.0	<12.8	168.6
24	—	R Orionis	52 13	+ 7 56.3	8.7 — 8.9	<13	378.8
25	877	ε Aurigæ	53 0	+43 38.2	3.0	4.5	Irr.
26	880	R Leporis	53 55	−14 59.7	6 — 7	8.5 ?	437.8
27	—	R Aurigæ	5 7 12	+53 26.6	6.5 — 7.4	12.5 — 12.7	465
27a	—	S Aurigæ	18 52	+34 2.3	9.4	<13	—
28	—	S Orionis	22 50	− 4 47.5	8.3 ?	<12.3	—
29	1005	δ Orionis	25 37	− 0 23.6	2.2 ?	2.7	Irr.
29a	—	Orionis	29 42	− 5 33.5	10	13	—
30	1091	α Orionis	48 24	+ 7 23.3	1	1.4	Irr.
31	1160	η Geminorum	6 7 20	+22 22.4	3.2	3.7 — 4.2	229.1
31a	—	Monocerotis	16 26	− 2 8.1	7	<10	—
32	1205	T Monocerotis	18 29	+ 7 9.1	6.2	7.6	26.8
33	—	R Monocerotis	32 21	+ 8 50.7	9.5	11.5	Irr.
34	1256	S Monocerotis	34 6	+10 0.5	4.9	5.4	3.4
35	—	R Lyncis	50 59	+55 30.2	9 ?	<12.3	—
36	1334	ζ Geminorum	56 41	+20 45.1	3.7	4.5	10.2
37	—	R Geminorum	59 49	+22 53.8	6.6 — 7.3	<12.3	371.0
38	—	R Canis min.	7 1 50	+10 13.1	7.2 — 7.9	9.5 — 10.0	335.0
38a	—	Puppis	9 43	−44 26.2	3½	<6	135
38b	—	V Geminorum	16 10	+13 21.8	8.5	12 — 13½	276
38c	1417	U Monocerotis	24 50	− 9 31.0	6.0	7.2	46.0
39	—	S Canis min.	25 56	+ 8 35.0	7.2 — 8.0	<11	332.2
40	—	T Canis min.	27 3	+12 0.6	9.1 — 9.7	<13	335.2
40a	—	Canis min.	34 34	+ 8 40.2	8½	13.5	405

TABLE I. — VARIABLE STARS.

No.	Class.	Discoverer.	Date.	Observations, 1884.
0a	—	Chandler	1881	35 Sr.
1	II.	Krüger	1870	4 C. 9 E. - Sk. 4 W.
2	II.	Argelander	1858	7 C. 3 D. 7 E. - Sk. 44 Sr. 8 W.
3	II.	Borelly	1872	1 C. 13 E. 2 P. - Sk.
4	I.	Tycho Brahe	1572	—
5	II.	Luther	1855	3 C. 7 E. 2 P.
6	III.	Birt	1831	1 B. 13 E. 27 Sr.
6a	V.	Ceraski	1880	4 Hg. 10 Hn. 7 W. 3 Zk.
7	II.	Argelander	1861	4 C. 26 P. - Sk.
8	II.	Hind	1851	2 C. 6 E.
8a	—	Peters	1880	10 P.
8b	—	Gould	1874?	4 Hn.
8c	II.	Gould	1872?	—
9	II.	Hind	1850	2 C. 1 E. - Sk.
10	II.	Peters	1865	4 C. 5 P.
11	II.	Argelander	1857	6 C. 18 Hn. 8 P. - Sk. 12 Zk.
12	II.	Fabricius	1596	17 B. 9 C. - Hg. - Sk. 24 Sr.
13	II.	Krüger	1873	5 C. 9 Hn. - Sk. 2 Zk.
14	II.	Argelander	1866	9 C. 5 P. - Sk.
15	II.	Auwers	1870	3 C. 22 Hn. - Sk. 12 Zk.
16	II.?	Schmidt	1854	47 Sr.
17	V.	Montanari	1669	6 B. 3 Hg. 1 Sr.
18	II.	Schönfeld	1861	10 C. 9 E. 19 Hn. - Sk. 4 W. 12 Zk.
19	V.	Baxendell	1848	2 B. 7 Zr.
20	—	Hind	1861	1 C. 4,1 K. 3 P. - Sk.
21	II.	Hind	1849	5 C. 10 E. 3 P. - Sk.
22	II.	Oudemans	1855	5 C. 8 E. 2 P. - Sk.
22a	—	Gould	1874?	—
23	II.	Auwers	1871	6 C. 9 P.
24	II.	Hind	1848	7 C. 1 E. 1,0 K.
25	III.	Fritsch	1821	6 P. 48 Sr.
26	II.	Schmidt	1855	5 C. 2,0 K. - Sk. 11 Sr.
27	II.	At Bonn	1862	7 C. 21 Hn. 2,0 K. - Sk. 14 Zk.
27a	II.	Dunér	1881	7 C. 5 D. 9 P.
28	II.	Webb	1870	6 C. 8 E. 7,6 K. 1 P. - Sk.
29	III.	J. Herschel	1834	28 Sr.
29a	—	Bond	1863	1 E. 1 P.
30	III.	J. Herschel	1836	3 Zr.
31	II.?	Schmidt	1866	6 B. 12 Sr.
31a	—	Schönfeld	1883	12 Sr.
32	IV.	Gould	1871	83 Sr.
33	II.	Schmidt	1861	3 C.
34	IV.	Winnecke	1867	29 Sr.
35	II.	Krüger	1874	11 C. 11 P.
36	IV.	Schmidt	1844	1 B. 24 Sr. 1 Zr.
37	II.	Hind	1848	6 C. 1,2 K. 25 P. 3 Sr.
38	II.	At Bonn	1854	9 C. 19 Hn. 2,0 K. 7 W. 17 Zk.
38a	II.	Gould	1872	7 C.
38b	II.	Baxendell	1880	23,9 K.
38c	II.?	Gould	1873	49 Sr.
39	II.	Hind	1856	9 C. 6,4 K. 6 W.
40	II.	Schönfeld	1865	4 C. 1,0 K.
40a	II.	Baxendell	1879	10 C. 29,6 K.

TABLE I. — *Continued.*

No.	H.P.	Name.	R. A. 1875.	Dec. 1875.	Max.	Min.	Per.
			h. m. s.	° ′	m.	m.	d.
41	—	S Geminorum	7 35 32	+23 44.6	8.2 — 8.7	<13	294.2
42	—	T Geminorum	41 48	+24 2.7	8.1 — 8.7	<13	288.1
42a	—	S Puppis	43 6	—47 8.3	7¼	9	—
43	—	U Geminorum	47 41	+22 19.7	8.9 — 9.7	13.1	Irr.
43a	—	Puppis	55 0	—12 32	8½	<14	310
44	—	R Cancri	8 9 40	+12 6.5	6.2 — 8.3	<11.7	354.4
45	—	V Cancri	14 36	+17 40.9	6.8 — 7.2	<12	272
46	—	U Cancri	28 37	+19 19.5	8.2 — 10.4	<13	305.7
47	—	S Cancri	36 48	+19 29.0	8.2	9.8	9.5
48	—	S Hydræ	47 3	+ 3 32.4	7.5 — 8.5	<12.2	256.4
49	—	T Cancri	49 32	+20 19.7	8.2 — 8.5	9.3 — 10.5	484.2
50	—	T Hydræ	49 35	— 8 39.8	7.0 — 8.1	<12.5	289.4
50a	—	R Carinæ	9 29 6	—62 14.2	4.4	9.3	313
51	—	R Leonis min.	38 4	+35 5.2	6.1 — 7.5	<11.0	374.7
52	1752	R Leonis	40 50	+12 0.5	5.2 — 6.4	9.4 — 10.0	312.6
52a	—	l Carinæ	41 49	—61 55.9	3.7	5.2	31.2
52b	—	Leonis	53 3	+21 51.6	8½	8.6<13	280?
52c	—	Antliæ	10 4 22	—37 7.1	6½	<8	—
52d	—	Carinæ	5 23	—60 56.3	6¼	9	—
52e	—	U Leonis	17 21	+14 38.1	9½	Inv.	—
52f	1869	Hydræ	31 22	—12 44.1	4½	6	—
53	1880	R Ursæ maj.	35 47	+69 25.9	6.0 — 8.1	12	303.4
54	—	η Argus	40 13	—59 1.6	>1	6.3	Irr.
54a	—	T Carinæ	50 18	—59 51.2	6.2	6.9	—
55	—	R Crateris	54 25	—17 39.2	>8	<9	—
56	—	S Leonis	11 4 23	+ 6 8.5	9.0 — 9.7	<13	187.6
57	—	T Leonis	32 2	+ 4 3.9	10?	<13	—
58	—	X Virginis	55 27	+ 9 46.1	7.8?	<10	—
59	—	R Comæ	57 51	+19 28.8	7.4 — 8.0	<13	363
60	—	T Virginis	12 8 12	— 5 20.4	8.0 — 8.8	<13	337
61	—	R Corvi	13 10	—18 33.5	6.8 — 7.3	<11.5	318.6
61a	—	— Virginis	27 26	— 3 43.8	8	14	210±
62	—	T Ursæ maj.	30 42	+60 10.6	7.0 — 8.3	12.2	255.6
63	2147	R Virginis	32 10	+ 7 40.6	6.5 — 7.5	10.0 — 10.9	145.7
63a	—	R Muscæ	34 28	—68 43.3	6.6	7.3	0.9
64	—	S Ursæ maj.	38 28	+61 46.7	7.7 — 8.2	10.2 — 11.1	224.8
65	—	U Virginis	44 46	+ 6 14.0	7.7 — 8.1	12.2 — 12.8	207.4
66	—	W Virginis	13 19 35	— 2 43.4	8.7 — 9.2	9.8 — 10.4	17.3
67	—	V Virginis	21 21	— 2 31.4	8.0 — 9.0	<13	251
68	2275	R Hydræ	22 53	—22 38.0	4.0 — 5.5	10?	469.3
69	2289	S Virginis	26 29	— 6 33.0	5.7 — 7.8	12.5	374.0
69a	—	Virginis	14 3 37	—12 42.7	9	14	—
69b	—	R Centauri	7 35	—59 19.8	6	10	—
70	—	T Bootis	8 14	+19 39.1	9.7?	<13	—
71	—	S Bootis	18 41	+54 22.7	8.1 — 8.5	13.2	272.4
72	—	R Camelopardi	27 8	+84 23.8	7.9 — 8.6	12?	266.2
73	2445	R Bootis	31 41	+27 16.9	5.9 — 7.5	11.3 — 12.2	223.0
73a	2459	Bootis	37 56	+27 3.6	5.2	6.1	370?
73b	—	Bootis	48 33	+18 12.1	9.1	12.0 — 13.6	173.8
74	2506	δ Libræ	54 18	— 8 1.2	4.9	6.1	2.3
74a	—	Libræ	15 3 37	—19 33.9	10	<13.5	700±
74b	—	R Triang. Austr.	8 37	—66 2.1	6.6	8.0	3.4
75	—	U Coronæ	13 6	+32 6.4	7.6	8.8	3.5
76	—	S Libræ	14 13	—19 56.1	8.0	12.5?	—
77	—	S Serpentis	15 48	+14 45.9	7.6 — 8.6	12.5?	361.0

TABLE I. — *Continued.*

No.	Class.	Discoverer.	Date.	Observations, 1884.
41	II.	Hind	1848	4 C.
42	II.	Hind	1848	8 C. 4 W.
42*a*	—	Gould	1874?	—
43	II.?	Hind	1855	18 C. 38,25 K. - Sk.
43*a*	II.	Pickering	1881	3 C.
44	II.	Schmidt	1829	5 C.
45	II.	Auwers	1870	9 C. 15 P. - Sk.
46	II.	Chacornac	1853	9 C. 16,15 K. - Sk. 3 W.
47	V.	Hind	1848	2 Hn.
48	II.	Hind	1848	5 C.
49	II.	Hind	1850	5 C. 18 P.
50	II.	Hind	1851	10 C.
50*a*	II.	Gould	1871	—
51	II.	Schönfeld	1863	7 C. 53 P. 20 Sr.
52	II.	Koch	1782	12 C. - Sk. 42 Sr. 12 W.
52*a*	—	Gould	1871	5 C.
52*b*	II.	Becker	1882	3 C.
52*c*	—	Gould	1872	—
52*d*	—	Gould	1871	—
52*e*	—	Peters	1876	—
52*f*	—	Gould	1871	—
53	II.	Pogson	1853	5 C. 22 Hn. 3,5 K. 32 Sr. 7 W. 15 Zk.
54	II.?	Burchell	1827	—
54*a*	—	Thome	1872	—
55	II.	Winnecke	1861	6 C. - Sk.
56	II.	Chacornac	1856	5 C. 3 W.
57	II.	Peters	1865	1 C.
58	II.	Peters	1871	5 C.
59	II.	Schönfeld	1856	4 C. 8,3 K. 19 P.
60	II.	Boguslawski	1849	5 C. 4 W.
61	II.	Karlinski	1867	10 C. - Sk.
61*a*	II.	Henry	—	9 C.
62	II.	Hencke	1856	11 C. - Sk. 26 Sr. 10 W.
63	II.	Harding	1809	8 C. 33 Sr. 10 W.
63*a*	IV.	Gould	1871	—
64	II.	Pogson	1853	11 C. 3,5 K. - Sk. 31 Sr. 10 W.
65	II.	Harding	1831	8 C. - Sk. 7 Sr.
66	II.?	Schönfeld	1866	11 C.
67	II.	Goldschmidt	1857	11 C. 9 P. 7 W.
68	II.	Miraldi	1704	4 C. - Sk. 26 Sr.
69	II.	Hind	1852	10 C. 16,0 K.
69*a*	II.	Palisa	1880	7 C.
69*b*	—	Gould	1871	—
70	I.?	Baxendell	1860	—
71	II.	At Bonn	1860	8 C. 11 Hn. - Sk. 3 W. 7 Zk.
72	II.	Hencke	1858	7 C. 10 P. - Sk. 4 W.
73	II.	At Bonn	1858	12 C. 6 Hn. - Sk. 46 Sr. 5 Zk.
73*a*	—	Schmidt	1867	9 C. 4 Zr.
73*b*	II.	Baxendell	1880	—
74	V.	Schmidt	1859	4 Zr.
74*a*	II.	Palisa	1878	5 C.
74*b*	IV.?	Gould	1871	—
75	V.	Winnecke	1869	8 Hn. 5 Zk.
76	II.	Borelly	1872	7 C. 8 P. - Sk.
77	II.	Harding	1828	10 C. 8 Hn. 7 Zk.

TABLE I. — *Continued.*

No.	H.P.	Name.	R. A. 1875.	Dec. 1875.	Max.	Min.	Per.
			h. m. s.	° ′	m.	m.	d.
78	2553	S Coronæ	15 16 18	+31 49.1	6.1 — 7.8	11.9 — 12.5	361.0
78a	—	Libræ	34 46	—20 46.5	9	<14	—
79	2639	R Coronæ	43 25	+28 32.5	5.8	13.0	Irr.
80	2647	R Serpentis	44 56	+15 30.8	5.6 — 7.6	<11	357.6
80a	—	V Coronæ	45 4	+39 57.0	7.7	12	360.0
81	—	R Libræ	46 32	—15 51.7	9.2 — 10.0	<13	723
82	2678	T Coronæ	54 16	+26 16.5	2.0	9.5	—
83	—	R Herculis	16 0 37	+18 42.5	8.0 — 9.0	<13	319.0
83a	—	W Scorpii	4 28	—19 48.6	10	<13	224.3
84	—	T Scorpii	9 36	—22 39.9	7	<10	—
85	—	R Scorpii	10 12	—22 38.2	9? — 10.5	<12.5	223
86	—	S Scorpii	10 13	—22 35.2	9.1 — 10.5	<12.5	176.9
86a	—	Ophiuchi	14 40	— 7 24.0	9.0	<13.5	326
87	—	U Scorpii	15 16	—17 35.3	9?	<12	—
87a	—	Ophiuchi	19 46	—12 8.5	7.5	10.5	365
88	—	U Herculis	20 16	+19 10.8	6.6 — 7.7	11.4 — 11.6	408.3
89	2772	g Herculis	24 32	+42 9.6	5	6.2	Irr.
90	—	T Ophiuchi	26 35	—15 51.8	10	<12.5	—
91	—	S Ophiuchi	27 4	—16 53.7	8.3 — 9.0	<12.5	233.8
91a	—	W Herculis	30 48	+37 35.6	8.0	<14.5	289
91b	—	Urs. Min.	31 40	+72 31.9	8.6	10.5	180?
91c	—	R Draconis	32 22	+67 0.7	7.2	13<	245.9
92	2828	S Herculis	46 13	+15 9.2	5.9 — 6.8	11.5 — 12.2	303
93	2839	Ophiuchi	52 30	—12 42.0	5.5	12.5	—
93a	—	V Herculis	53 41	+35 15.5	9.0	11.7	—
94	—	R Ophiuchi	17 0 36	—15 55.5	7.6 — 8.1	<12	302.4
95	2879	α Herculis	8 57	+14 32.1	3.1	3.9	Irr.
95a	2883	U Ophiuchi	10 12	+ 1 21.0	6.1	6.8	0.9
96	2890	u Herculis	12 42	+33 14.1	4.6	5.4	38.5
97	—	Serpentarii	23 9	—21 22.4	>1	?	—
98	2972	X Sagittarii	39 41	—27 46.8	4	6	7.0
99	3035	W Sagittarii	57 2	—29 35.1	5	6.5	7.6
100	—	T Herculis	18 4 22	+31 0.1	7.2 — 8.3	11.4 — 12.1	165.1
101	—	T Serpentis	22 43	+ 6 13.1	9.1 — 10.0	<12.8	342.3
102	—	V Sagittarii	24 4	—18 20.9	7.5?	9.5?	—
103	—	U Sagittarii	24 32	—19 12.7	7.0	8.3	6.7
104	—	T Aquilæ	39 45	+ 8 36.9	8.8	9.5	Irr.
105	3176	R Scuti	40 49	— 5 50.2	4.7 — 5.7	6.0 — 8.5	71.1
105a	—	κ Pavonis	44 3	—67 23.2	4.0	5.5	9.1
106	3193	β Lyræ	45 28	+33 13.0	3.4	4.5	12.9
107	3224	R Lyræ	51 32	+43 47.1	4.3	4.6	46.0
108	—	S Coron. Austr.	52 43	—37 7.2	9.8	11.5?	6.1
109	—	R Coron. Austr.	53 29	—37 7.2	10.5 — 11.5	<12.5	31
110	—	R Aquilæ	19 0 21	+ 8 2.6	6.4 — 7.4	10.9 — 11.2	345.1
111	—	T Sagittarii	9 1	—17 11.2	7.6 — 8.1	<11	381
112	—	R Sagittarii	9 21	—19 31.5	7.0 — 7.2	<12	270.0
113	—	S Sagittarii	12 7	—19 15.1	9.7 — 10.4	<12.7	230
114	3395	R Cygni	33 28	+49 55.1	5.9 — 8.0	13	425.3
115	—	11 Vulpeculæ	42 26	+27 0.5	3	?	—
116	—	S Vulpeculæ	43 16	+26 58.7	8.4 — 8.9	9.0 — 9.5	67.5
117	3434	χ Cygni	45 46	+32 36.0	4.0 — 6.0	12.8	406.5
118	3436	η Aquilæ	46 6	+ 0 41.2	3.5	4.7	7.2
119	—	S Cygni	20 2 53	+57 37.6	8.8 — 9.5	<13	322.8
120	—	R Capricorni	4 17	—14 38.2	8.8 — 9.7	<13	347
121	—	S Aquilæ	5 52	+15 14.9	8.9 — 9.9	10.7 — 11.8	147.2

TABLE I. — *Continued.*

No.	Class.	Discoverer.	Date.	Observations, 1884.
78	II.	Hencke	1860	5 C. 8 Hn. 2,1 K. - Sk. 45 Sr. 10 W. 5 Zk.
78*a*	—	Peters	1878	—
79	II.?	Pigott	1795	6 C. - Sk. 88 Sr. 10 W.
80	II.	Harding	1826	9 C. 5 P.
80*a*	II.	Dunér	1878	3 C. 15 D. - Sk. 8 W.
81	II.	Pogson	1858	8 C. 1,1 K.
82	I.	Birmingham	1866	21 B. 7 Hn. 3,1 K. 2 P. 4 Zk.
83	II.	At Bonn	1855	2 C. 10 Hn. 4 P. 6 Zk.
83*a*	II.	J. Palisa	1877	4 C. 6 P.
84	I.	Auwers	1860	3 C.
85	II.	Chacornac	1853	6 C. 11,1 K. 6 P.
86	II.	Chacornac	1854	6 C. 7,1 K. 6 P.
86*a*	II.	Schönfeld	1881	7 C.
87	I.?	Pogson	1863	—
87*a*	—	Dunér	1881	8 C. 11 D.
88	II.	Hencke	1860	3 C.
89	III.	Baxendell	1857	83 Sr.
90	II.	Pogson	1860	2 C.
91	II.	Pogson	1854	2 C. 1 Hn.
91*a*	—	Dunér	1880	14 C. 8 Hn. 9 P. 4 W. 5 Zk.
91*b*	II.	Pickering	1881	11 C. 1,1 K. - Sk.
91*c*	II.	Geelmuyden	1876	9 C. - Sk. 35 Sr. 12 W.
92	II.	At Bonn	1856	4 C. 10 Hn. - Sk. 7 Zk.
93	I.	Hind	1848	—
93*a*	II.	Baxendell	1880	9 C.
94	II.	Pogson	1853	8 C.
95	III.	W. Herschel	1795	3 Zr.
95*a*	V.	Sawyer	1881	5 Sr. 4 W.
96	III.	Schmidt	1869?	3 Zr.
97	I.	Fabricius	1604	2 Zr.
98	IV.	Schmidt	1866	29 Sr.
99	IV.	Schmidt	1866	35 Sr.
100	II.	At Bonn	1857	7 C. 11 Hn. - Sk. 7 Sr. 6 W. 6 Zk.
101	II.	Baxendell	1860	2 C.
102	II.	Quirling	1865	2 C.
103	IV.	Schmidt	1866	1 C.
104	II.	Winnecke	1860	1 C.
105	II.	Pigott	1795	89 Sr.
105*a*	IV.	Thome	1872	—
106	IV.	Goodricke	1784	10 Zr.
107	II.?	Baxendell	1856	62 Sr.
108	IV.?	Schmidt	1866	—
109	II.?	Schmidt	1866	—
110	II.	At Bonn	1856	1 C. - Sk.
111	II.	Pogson	1863	1 C. - Sk.
112	II.	Pogson	1858	5 P. - Sk.
113	II.	Pogson	1860	10 P. - Sk.
114	II.	Pogson	1852	3 C. 9 Hn. 12 P. - Sk. 5 Zk.
115	I.	Anthelm	1670	2 Zr.
116	II.	Hind	1861	4 C. 13 Hn. 5,0 K. 4 W. 6 Zk.
117	II.	Kirch	1686	2 C. 2 Hn. 56 P. - Sk. 41 Sr. 5 W. 2 Zk.
118	IV.	Pigott	1784	79 Sr.
119	II.	At Bonn	1860	6 C. 7,17 K. 18 P.
120	II.	Hind	1848	- Sk.
121	II.	Baxendell	1863	2 C. 11 E. 2 P. 12,14 K.

TABLE I. — *Continued.*

No.	H.P.	Name.	R. A. 1875.	Dec. 1875.	Max.	Min.	Per.
			h. m. s.	° ′	m.	m.	d.
122	—	R Sagittæ	20 8 22	+16 21.0	8.5 — 8.7	9.8 — 10.4	70.4
123	—	R Delphini	8 53	+ 8 42.7	7.6 — 8.5	12.8	284.0
124	3547	P Cygni	13 11	+37 38.7	3 — 5	<6	—
125	—	U Cygni	15 44	+47 30.1	7.8 ?	9.8 ?	—
126	3557	R Cephei	34 29	+88 45.2	5 ?	10 ?	—
126*a*	—	— Cygni	37 17	+47 41.8	8	12	423.
127	—	S Delphini	37 19	+16 38.4	8.4 — 8.6	10.4 — 11.1	275.6
128	—	T Delphini	39 34	+15 56.7	8.2 — 8.9	<13	331.4
129	—	U Capricorni	41 11	—15 14.4	10.2 — 10.8	<13	203.5
130	3654	T Cygni	42 12	+33 55.0	5.5 ?	6 ?	—
131	—	T Aquarii	43 20	— 5 36.5	6.7 — 7.0	12.4 — 12.7	203.2
132	—	R Vulpeculæ	58 49	+23 19.5	7.5 — 8.5	12.5 — 13.0	137.5
132*a*	—	Capricorni	21 0 19	—24 25.5	9½	14	—
132*b*	—	T Cephei	7 52	+67 58.9	5.6	9.5	382
133	—	T Capricorni	15 6	—15 41.4	8.9 — 9.7	<13	269.4
134	—	S Cephei	36 45	+78 3.6	7.4 — 8.5	11.5	485
134*a*	—	Nova Cygni	37 2	+42 18.2			—
135	3845	μ Cephei	39 41	+58 12.4	4 ?	5 ?	Irr.
136	—	T Pegasi	22 2 48	+11 55.7	8.8 — 9.3	<12.5	367.5
137	3981	δ Cephei	24 32	+57 46.6	3.7	4.9	5.4
137*a*	—	Lacertæ	37 43	+41 43.0	8.6	<13.5	315.
138	—	S Aquarii	50 25	—21 0.6	7.7 — 9.1	<11.5	279.4
139	4078	β Pegasi	57 45	+27 24.2	2.2	2.7	Irr.
140	—	R Pegasi	23 0 22	+ 9 52.1	6.9 — 7.7	12 ?	382.0
141	—	S Pegasi	14 14	+ 8 14.2	7.6	<12.2	—
142	4193	R Aquarii	37 21	—15 58.7	5.8 — 8.5	11 ?	388.0
143	4234	R Cassiopeiæ	52 4	+50 41.5	4.8 — 6.8	<12	425.9

Remarks.

2. Max. 1883, December 1. Sr.

6. Light has remained nearly constant. Sr.

6*a*. Min. 1884, February 19, March 15, August 24, September 8. Hg.

12. Max. 1884, March 6 (approximate). Magn. 4.6. Sr.

16. Light has remained nearly constant. Sr.

17. Min. 1884, February 5, February 28, September 27. Hg. — 1884, November 29, 13h. 39m. G. M. T. Duration of observations, 4h. 35m. Sr.

25. Max. 1884, February 27. Min. 1884, January 18, March 18. Sr.

27*a*. Approximate period, 270 days. D.

29. Light apparently constant. Sr.

31*a*. Max. 1884, December 10 (approximate). Sr.

38*b*. Max. 1883, February 25. Magn. 8.6. K.

38*c*. Max. 1884, February 3, March 11. Min. 1884, January 5, February 24, April 9. Sr.

43. Max. 1883, October 25; 1884, January 28, October 24. Hg. — 1883, January 30 (approximate). Magn. about 9.5. 1884, January 26. Magn. 9.6. 1884, May 15 (approximate). 1884, October 22. Magn. 9.4. K.

46. Max. 1884, March 8. Magn. 8.5. K.

52. Max. 1884, February 5 (approximate). Magn. 6.7. Sr.

TABLE I. — *Continued.*

No.	Class.	Discoverer.	Date.	Observations, 1884.
122	II.?	Baxendell	1859	2 C. 22 E. 11 Hn. 1 P. 5 Zk.
123	II.	Hencke	1859	1 C. 8 Hn. - Sk. 4 Zk.
124	I.	Janson	1600	11 Zr.
125	II.	Knott	1871	3 C. 13,20 K. 16 P. - Sk.
126	II.?	Pogson	1856	1 C. 32 E. - Sk.
126*a*	II.	Birmingham	1881	- Hg. 11,8 K. 5 P.
127	II.	Baxendell	1860	2 C. 12 E. 8 P. - Sk.
128	II.	Baxendell	1863	4 C. 12 E. 18,17 K. - Sk. 4 W.
129	II.	Pogson	1858	13 P.
130	—	Schmidt	1864	7 E. 35 Sr.
131	II.	Goldschmidt	1861	3 C. 12 P. - Sk.
132	II.	At Bonn	1858	4 C. 12 E. 13,16 K. 2 P. 5 W.
132*a*	—	Peters	1867	12 C. 7 P.
132*b*	II.?	Ceraski	1878	12 E. - Hg. 29,25 K. - Sk. 4 W.
133	II.	Hind	1854	9 P.
134	II.	Hencke	1858	6 C. 12 E. - Sk.
134*a*	I.	Schmidt	1876	—
135	III.?	Hind	1848	2 B. 1 C. 12 E. 1 P. - Sk. 10 Zr.
136	II.	Hind	1863	2 C. 9 P.
137	IV.	Goodricke	1784	10 Zr.
137*a*	—	Deichmüller	1883	4 C. 7 E. - Hg. 6,16 K.
138	II.	Argelander	1853	4 P. - Sk.
139	III.	Schmidt	1847	9 B. 28 Sr.
140	II.	Hind	1848	1 C. 5 E. 1 P.
141	II.	Marth	1864?	4 C. 2 E.
142	II.	Harding	1811	4 C. 8 P. - Sk. 21 Sr.
143	II.	Pogson	1853	8 C. 1,0 K. 8 P. - Sk.

53. Max. 1884, August 29. Magn. 7.1. Sr.

62. Max. 1884, October 17. Magn. 7.8. Sr.

63. Max. 1884, April 11. Magn. 7.1. Sr.

64. Max. 1884, September 17 ± 1 day. Magn. 7.7. Sr.

73. Max. 1884, October 5. Magn. 7. 5. Sr.

78. Max. 1884, May 5. Magn. 7.3. Sr.

79. Slight fluctuations of light. Sr.

80*a*. Max. 1878, October 21.7. Period, 356.02 days. D.

85. Max. 1883, July 9. Magn. 10.1. K.

87*a*. V *Ophiuchi*. Approximate period 300 days. D.

89. Max. 1884, June 27, September 8, October 22. Min. 1884, May 30, August 4, September 23, November 14. Sr.

91*c*. Max. 1884, September 5. Magn. 7.5. Sr.

105. Max. 1884, June 7, August 3, October 17, November 30 (approximate). Min. 1884, July 12, September 15, November 11. Sr.

107. Two remarkable outbursts of light observed in 1884, from November 7 to 11, and from November 21 to 30. Sr.

117. Max. 1884, November 23. Magn. 5.4. Sr.

119. Max. 1884, early in December. K.

125. Max. 1884, February 1. Magn. 7.8. Period, 461 days. Min. 1883, June 14. Magn. 11.5. 1884, September 21. Magn. 11.1. K.

TABLE II. — INDEX TO DESIGNATIONS.

Constellation.	R.	S.	T.	U.	V.	W.	Misc.
Andromeda	2	....	....	....	....	....	
Antlia	....	....	....	....	....	....	–,52*c*.
Aquarius	142	138	131	....	....	....	
Aquila	110	121	104	....	....	....	η,118.
Argo	....	....	....	....	....	....	η,54.
Aries	11	10	15	....	....	....	
Auriga	27	27*a*	....	....	....	....	ϵ,25.
Bootes	73	71	70	....	....	....	–,73*a*. –,73*b*.
Camelopardus	72	....	....	....	....	....	
Cancer	44	47	49	46	45	....	
Canis Minor	38	39	40	....	....	....	–,40*a*.
Capricornus	120	....	133	129	....	....	–,132*a*.
Carina	50*a*	....	54*a*	....	....	....	*l*,52*a*. –,52*d*.
Cassiopeia	143	7	1	....	....	....	B,4. α,6.
Centaurus	69*b*	....	....	....	....	....	
Cepheus	126	134	132*b*	6*a*	....	....	μ,135. δ,137.
Cetus	14	3	....	....	....	....	–,0*a*. –,8*b*. *o*,12.
Coma Beren.	59	....	....	....	....	....	
Corona Aus.	109	108	....	....	....	....	
Corona Bor.	79	78	82	75	80*a*	....	
Corvus	61	....	....	....	....	....	
Crater	55	....	....	....	....	....	
Cygnus	114	119	130	125	....	....	χ,117. P,124. –,126*a*. Nova, 134*a*.
Delphinus	123	127	128	....	....	....	
Doradus	....	....	....	....	....	....	–,22*a*.
Draco	91*c*	....	....	....	....	....	
Gemini	37	41	42	43	38*b*	....	η,31. ζ,36.
Hercules	83	92	100	88	93*a*	91*a*	*g*,89. α,95. *u*,96.
Hydra	68	48	50	....	....	....	–,52*f*.
Lacerta	....	....	....	....	....	....	–,137*a*.
Leo	52	56	57	52*e*	....	....	–,52*b*.
Leo Minor	51	....	....	....	....	....	
Lepus	26	....	....	....	....	....	
Libra	81	76	....	....	....	....	δ,74. –,74*a*. –,78*a*.
Lynx	35	....	....	....	....	....	
Lyra	107	....	....	....	....	....	β,106.
Monoceros	33	34	32	38*c*	....	....	–,31*a*.
Musca	63*a*	....	....	....	....	....	
Ophiuchus	94	91	90	95*a*	....	....	–,86*a*. –,87*a*. –,93. Nova, 97.
Orion	24	28	....	....	....	....	δ,29. –,29*a*. α,30.
Pavo	....	....	....	....	....	....	κ,105*a*.
Pegasus	140	141	136	....	....	....	β,139.
Perseus	18	13	....	....	....	....	ρ,16. β,17.
Pisces	9	8	5	....	....	....	–,8*a*.
Puppis	....	42*a*	....	....	....	....	–,38*a*. 43*a*.
Sagitta	122	....	....	....	....	....	
Sagittarius	112	113	111	103	102	99	X,98.
Scorpius	85	86	84	87	....	83*a*	
Sculptor	8*c*	....	....	....	....	....	
Scutum	105	....	....	....	....	....	
Serpens	80	77	101	....	....	....	
Serpentarius	....	....	....	....	....	....	See Ophiuchus.
Taurus	21	22	20	....	23	....	λ,19.
Triang. Aus.	74*b*	....	....	....	....	....	
Ursa Major	53	64	62	....	....	....	
Ursa Minor	....	....	....	....	....	....	–,91*b*.
Virgo	63	69	60	65	67	66	X,58. –,61*a*. –,69*a*.
Vulpecula	132	116	....	....	....	....	11,115.

128. Max. 1883, October 6. Magn. 9.6. 1884, September 15. Magn. 9.0. K.

132. Min. 1884, August 10. Magn. 12.7. Max. 1884, October 15. Magn. 7.6. K.

132*b*. Max. 1883, February 6. Magn. 6.3. 1884, March 7. Magn. 6.8. Min. 1883, August 23. Magn. 9.9. 1884, August 11. Magn. 9.7. K.

142. Max. 1883, December 25 (approximate). Magn. 6.3. Sr.

Table II. enables the number of any star in Table I. to be found from its usual designation. The constellations are arranged alphabetically in the first column, and the numbers are placed under the respective headings R, S, T, U, V, and W. Thus R, S, and T *Aquarii* are respectively Nos. 142, 138, and 131 in Table I. In the column headed "Misc." are given other designations; thus η *Aquilæ* is No. 118, and η *Argus* is No. 54. The number is preceded by a dash when no letter has been definitely assigned to the corresponding star; thus, -,52*c* in the second line indicates that a variable star in *Antlia*, No. 52*c* in Table I., has not been definitely designated by a letter.

The list of suspected variables, given in Table II. of the statement made in 1884, is not here repeated, since from the nature of the case such a list can only be provisional. It should be remarked that all the stars which were inserted on the authority of Dr. Peters are considered by him to be certainly variable. Dr. Dunér also furnishes the place of a variable star which he observed on 23 days in 1884; it was not given in either of the tables published last year. The place, reduced to 1875, is as follows: R. A. 14h. 24m. 41s., δ +39° 25′.2. The period is about 405 days. Four variable stars were detected by means of the observations made for the Cordoba Zone-Catalogue; see that work, p. xiv., and Dr. Gould's letter in the Astronomische Nachrichten, CXI. 63. The places for 1875 are as follows: R. A. 15h. 45m. 22s., Dec. —35° 55′.3; R. A. 22h. 10m. 53s., Dec. —30° 13′.6; R. A. 22h. 27m. 4s., Dec. —67° 55′.9; R. A. 23h. 49m. 58s., Dec. —50° 28′.9.

Table III. indicates the progress of observation of suspected variables given in Table II. of the statement made in 1884. The stars are designated in the first column by Mr. Chandler's provisional numbers, as in the previous statement. The second column gives the number of observations made by each observer, as in the last column of Table I. The third column indicates the result of these observations.

TABLE III. — OBSERVATIONS OF SUSPECTED VARIABLES.

No.	Obs. 1884.	Results.	No.	Obs. 1884.	Results.
1	17 Hn.	Constant.	345	16 Hn. 14 Zk.	Constant.
9	11 P.		347	32 Hn. 29 Zk.	Constant.
47	2 B.		365	16 Hn. 16 Zk.	Constant.
73	7 P.		373	28 Hn. 25 Zk.	Constant.
81	1 B.		407	14 Hn. 14 Zk.	Doubtful.
87	9 P.		459	6 P.	Variable.
93	5 K.		471	4 P.	
111	2 B. 7 Hn. 4 Zk.	Constant.	509	1 B. 28 Hn. 20 Zk.	Constant.
113	5 Hn. 8 Zk	Constant.	547	2 B. 22 Hn. 12 Zk.	Constant.
139	5 P.		567	7 P.	
143	7 P.		601	5 P.	
145	8 Hn. 8 Zk.	Constant.	615	14 P.	
147	9 Hn. 8 Zk.	Constant.	625	13 Hn.	Constant.
205	21 P.	Prob. var.	635	2 K.	
294	11 P.	Variable.			

It is hoped that observers of variable stars will continue to furnish accounts of their work during each year as soon as possible after its close. It is desirable that these accounts should be received at the Harvard College Observatory as early as February 1 of the following year.

INVESTIGATIONS ON LIGHT AND HEAT, MADE AND PUBLISHED WHOLLY OR IN PART WITH APPROPRIATION FROM THE RUMFORD FUND.

XVIII.

A PHOTOGRAPHIC STUDY OF THE NEBULA OF ORION.

BY EDWARD C. PICKERING.

Presented March 11, 1885.

No portion of the heavens has been more carefully studied than that containing the Nebula of Orion. The monographs by Prof. G. P. Bond (Annals Harvard College Observatory, V.) and by Prof. E. S. Holden (Washington Astronomical Observations for 1878, Appendix I.) show the vast amount of material collected by eye observations. For a photographic study of the same region the following specimens are in the photographic collection of the Harvard College Observatory: —

A. Artotype enlargement of the first photograph of the nebula taken by Dr. Henry Draper, September 30, 1880. Exposure, 51 minutes.

B. Artotype enlargement of a photograph taken by Dr. Henry Draper, March 11, 1881. Exposure, 106 minutes.

C. The original negative taken by Dr. Henry Draper on March 14, 1882. Exposure, 136 minutes. This negative, except for a slight photographic blemish, is nearly identical with that from which D. was taken.

D. An enlarged glass positive of the second photograph taken by Dr. Henry Draper, March 14, 1882. Exposure, 137 minutes. This positive is a duplicate of that employed in making the paper prints, E. The two positives were taken, and any objects resembling stars, but not found on both, were assumed to be defects, and were painted out of the other positive by Dr. Draper.

E. Several artotype enlargements of the second photograph, taken March 14, 1882, by Dr. Henry Draper.

F. Carbon print of photograph taken by Mr. Common with his 3-foot reflector, January 30, 1883. Exposure, 39 minutes. Enlargement about 7 times.

G. Glass positive, — a direct copy of the negative taken by Mr. Common with his 3-foot reflector, February 26, 1883. Exposure, 60 minutes.

Admirable material is thus furnished for a comparison of the results of photographic and eye observations of this region. The photographs of the stars which are common to F and to the catalogue of Professor Bond (Annals, V. 270) were first compared by a method closely resembling that adopted by Argelander for the study of variable stars. Table I. gives the stars which were selected for standards, with which the others are to be compared. Each star in the photograph was then compared with two of these, — one a little brighter, the other a little fainter. The differences were estimated in grades. The sum of the two differences gave a measure of the interval between the two comparison stars. It frequently happened that no difference in brightness was perceptible between the star to be measured and one of the comparison stars. The number of measures of star intervals between the comparison stars is therefore less than the number of stars compared. In Table I. the successive columns give for each comparison star a designation, and the number and magnitude in the Bond catalogue. The next column gives the photographic magnitude, found by a process which will be detailed below. This is followed by the number of comparisons between each star and that following it, and the mean value of this difference in grades. The last column gives the assumed brightness in grades, and equals the number of grades by which each star is fainter than the first on the list.

TABLE I.

Desig.	Bond No.	Bond Magn.	Photog. Magn.	No. Comp.	Diff. Grades.	Grades.
a	570	9.4	9.4	1	1.0	0
b	505	11.3	9.5	3	3.0	1
c	523	10.1	9.8	2	2.5	4
d	479	10.0	10.1	5	2.4	7
e	449	10.5	10.4	8	3.0	9
f	427	10.7	10.9	8	3.0	12
g	506	11.3	11.3	5	2.0	15
h	458	11.2	11.6	7	4.2	17
i	373	12.0	12.3	3	3.0	21
j	409	13.9	13.0	9	2.9	24
k	378	14.8	13.8	6	3.0	27
l	490	14.2	14.8	5	2.8	30
m	737	15.0	15.6	....	....	33

The light of each star measured was next reduced to grades by the assumed light in grades of the comparison stars. Two values were found, — one derived from the brighter, the other from the fainter comparison star. In 50 cases the results agreed exactly, in 11 cases

they differed by one grade, and in one case only by two grades. The relation between the grades and the scale of magnitude of the Bond Catalogue was next found by grouping the stars by half-magnitudes. The middle points of each group are given in the first column of Table II., the number of stars in the group in the second column, and the mean of the corresponding values in grades in the third. Points were then constructed with the first and third columns as ordinates, and a smooth curve drawn through them. The comparative values of the

TABLE II.

Bond Magn.	No. Stars.	Gr.	Bond Magn.	No. Stars.	Gr.
9.5	2	0.5	13.0	7	22.7
10.0	10	6.1	13.5	4	27.5
10.5	11	9.4	14.0	14	27.2
11.0	11	11.9	14.5	....	....
11 5	12	16.8	15.0	9	30 6
12.0	3	18.7	16.5	1	37.0
12.5	9	24.8			

grades and magnitudes derived from this curve are given in Table III. Applying the results of this table to the last column of Table I. gives the fourth column of that table. The results for all the stars in the Bond Catalogue differing less than 1000$''$ in right ascension and declination from θ' *Orionis*, the brightest star in the nebula, are given

TABLE III.

Gr.	Magn.	Gr.	Magn.	Gr.	Magn.
0	9.4	12	10.9	24	13.0
1	9.5	13	11.0	25	13.2
2	9.6	14	11.2	26	13.5
3	9.7	15	11.3	27	13.8
4	9.8	16	11.5	28	14.1
5	9.9	17	11.6	29	14.5
6	10.0	18	11.8	30	14.8
7	10.1	19	12.0	31	15.1
8	10.3	20	12.1	32	15.3
9	10.4	21	12.3	33	15.6
10	10.6	22	12.5	34	15.8
11	10.7	23	12.7	35	16.1

in Table IV. The first four columns give the number, difference in right ascension and declination from θ' *Orionis*, and magnitude according to the Bond Catalogue. The fifth column gives the magnitude found as described above from F, the photograph of Mr. Common.

TABLE IV.

Bond No.	Δα.	Δδ.	Bond Magn.	Common Magn.	Draper Magn.	Resid. Common.	Resid. Draper.
303	—979.2	+ 13.9	9.9	10.0	....	+ 1	....
311	—928.2	+681.9	10.7	*a*	....	....	....
314	—923.1	—307.8	11.4	11.6	....	+ 2	....
315	—921.3	—825.4	10.2	10.3	....	+ 1	....
323	—886.4	—816.6	10.7	10.7	....	0	....
329	—867.6	—626.9	14.2	*d*	....	....	....
332	—863.9	—646.8	14.8	*d*	....	....	....
335	—851.6	—239.0	10.9	10.6	....	— 3	....
339	—839.7	—446.6	14.8	14.8	....	0	....
346	—833.4	—947.1	10.7	10.9	....	+ 2	....
347	—829.4	—462.6	14.8	*c*	....	....	....
363	—772.4	+ 66.3	10.7	10.3	....	— 4	....
370	—746.6	— 66.8	13.3	14.1	....	+ 8	....
373	—732.9	— 70.5	12.0	12.3	....	+ 3	....
377	—724.1	—525.0	11.3	11.5	....	+ 2	....
378	—720.3	—107.1	14.8	13.8	....	—10	....
382	—703.5	— 45.0	11.7	11.2	....	— 5	....
387	—687.6	—252.2	10.4	10.2	....	— 2	....
399	—644.9	+ 15.4	12.5	12.5	....	0	....
402	—635.1	—314.2	12.3	11.3	....	—10	....
409	—608.9	—539.2	13.9	13.0	....	— 9	....
413	—593.4	—776.6	15.0	14.8	....	— 2	....
419	—574.7	—701.7	14.2	*d*	....	....	....
423	—558.3	+790.8	10.8	*a*	....	....	....
427	—546.6	— 71.1	10.7	10.9	11.6	+ 2	+ 9
430	—542.2	—206.8	11.7	11.5	11.8	— 2	+ 1
435	—530.1	+ 30.9	13.1	12.0	....	—11	....
438	—525.9	+963.4	9.4	*a*	....	....	....
443	—519.6	+649.4	13.1	*c*	....	....	....
449	—495.5	+290.3	10.5	10.4	10.8	— 1	+ 3
458	—464.7	—107.8	11.2	11.6	12.0	+ 4	+ 8
464	—442.5	—946.4	14.2	14.8	....	+ 6	....
467	—431.0	—658.6	8.7	8.8	9.4	+ 1	+ 7
471	—420.0	—836.5	14.8	14.8	....	0	....
479	—400.4	+272.3	10.0	10.1	10.5	+ 1	+ 5
490	—380.7	— 49.3	14.2	14.8	....	+ 6	....
497	—356.1	—592.2	9.9	10.3	10.7	+ 4	+ 8
505	—309.6	—424.7	9.6	9.6	9.6	0	0
506	—306.0	+ 5.6	11.3	11.3	11.4	0	+ 1
508	—300.9	+704.3	12.3	14.5	....	+22	....
510	—290.9	—505.9	13.1	13.5	....	+ 4	....
516	—276.0	— 29.5	13.5	13.8	....	+ 3	....
523	—242.3	—116.0	10.1	10.2	10.0	+ 1	— 1
524	—241.4	+ 16.8	12.5	13.4	....	+ 9	....
532	—218.6	+449.6	14.2	*d*	....	....	....
543	—196.1	+909.4	10.3	*a*	....	....	....
545	—195.5	—401.3	13.1	13.8	....	+ 7	....
551	—175.1	+510.8	10.1	11.0	11.4	+ 9	+13
552	—169.2	—393.3	14.9	*d*	....	....	....
554	—163.1	+666.0	9.0	9.4	9.4	+ 4	+ 4
558	—158.9	—118.6	10.7	11.7	11.2	+10	+ 5
563	—120.0	+990.6	14.4	*a*	....	....	....
566	—104.1	—406.3	13.3	13.0	....	— 3	....
567	—102.8	— 8.3	13.9	*b*	....	....	....
570	— 94.8	—273.2	9.4	9.4	9.3	0	— 1

TABLE IV. — *Continued.*

Bond No.	Δα.	Δδ.	Bond Magn.	Common Magn.	Draper Magn.	Resid. Common.	Resid. Draper.
573	—87.3	—179.0	13.9	12.5	....	— 6	....
575	—84.8	— 22.3	11.9	*b*	....	....	....
580	—77.6	+385.8	12.3	14.5	11.9	+22	— 4
581	—76.1	—159.1	14.2	*b*	....	....	....
583	—74.0	—914.	11.5	12.0	....	+ 5	....
587	—61.5	—806.5	13.9	13.2	....	— 7	....
589	—57.2	— 20.4	12.7	*b*	....	....	....
595	—46.9	— 15.0	13.9	*b*	....	....	....
598	—38.6	—455.1	12.3	12.0	12.0	— 3	— 3
599	—36.5	—974.1	11.8	11.2	....	— 6	....
601	—36.	— 31.	15.6	*b*	....	....	....
602	—33.0	— 67.5	14.3	*b*	....	....	....
605	—27.8	—953.3	13.9	13.2	....	— 7	....
608	—23.7	— 18.0	14.3	*b*	....	....	....
612	—16.4	+ 24.6	13.5	*b*	....	....	....
615	—12.0	+500.5	14.2	*d*	....	....	....
617	—10.7	+ 12.9	....	*b*	....	....	....
618	—10.4	+ 24.6	13.1	*b*	....	....	....
619	—10.0	+ 8.7	....	*b*	....	....	....
620	— 9.0	—953.3	13.1	12.5	....	— 6	....
621	— 8.	— 36.	15.6	*b*	....	....	....
622	— 7.5	— 27.8	12.7	*b*	....	....	....
624	— 5.0	+ 16.1	....	*b*	....	....	....
625	— 4.	— 28.	15.6	*b*	....	....	....
628	0.0	0.0	....	*b*	....	....	....
631	+ 3.	— 42.	14.3	*b*	....	....	....
633	+ 3.5	— 2.1	....	*b*	....	....	....
635	+ 8.3	+ 98.3	10.5	10.9	10.7	+ 4	+ 2
636	+ 8.4	— 8.7	13.3	*b*	....	....	....
639	+11.0	—951.5	11.1	10.6	....	— 5	....
640	+11.5	+ 6.8	....	*b*	....	....	....
641	+11.9	+111.2	14.8	*d*	....	....	....
642	+13.	+ 48.	15.6	*b*	....	....	....
647	+22.6	+ 38.0	12.1	*b*	10.3	....	—18
648	+24.2	— 8.7	14.3	*b*	....	....	....
650	+28.5	+408.8	13.1	15.2	12.0	+21	—11
651	+29.4	+ 47.8	13.1	*b*	....	....	....
652	+30.2	+171.6	13.9	13.4	....	— 5	....
653	+30.8	+429.7	13.9	13.5	12.2	— 4	—17
654	+33.2	+ 10.0	12.3	*b*	....	....	....
657	+39.6	+165.2	13.1	12.0	11.6	—11	—15
663	+55.5	+147.1	11.7	14.8	11.2	+31	— 5
666	+59.7	—195.8	13.9	13.8	....	— 1	....
667	+60.5	+848.9	9.4	*a*	....	....	....
669	+63.3	+100.0	9.8	10.4	10.2	+ 6	+ 4
670	+64.2	+673.2	10.8	10.8	10.9	0	+ 1
671	+69.6	— 24.4	11.5	*b*	....	....	....
674	+73.6	+976.5	14.2	*a*	....	....	....
675	+74.5	— 93.4	15.2	*b*	....	....	....
676	+78.5	— 27.6	13.1	*b*	....	....	....
677	+78.6	—201.4	14.8	14.8	....	0	....
678	+79.2	+852.2	13.9	*a*	....	....	....
680	+82.2	—675.3	13.9	11.6	....	—23	....
681	+90.3	+173.2	14.8	13.2	....	—16	....
684	+96.8	+744.8	14.5	*a*	....	....	....

TABLE IV. — *Continued.*

Bond No.	Δα.	Δδ.	Bond Magn.	Common Magn.	Draper Magn.	Resid. Common.	Resid. Draper
685	+ 97.7	— 95.0	8.3	8.8	....	+ 5	....
686	+100.	— 39.	15.6	*b*	....	....	....
688	+106.	— 18.	15.6	*b*	....	....	....
690	+119.4	—443.7	10.3	10.9	11.2	+ 6	+ 9
693	+131.7	+751.6	13.9	*a*	....	....	....
695	+132.8	+818.1	12.5	*a*	....	....	....
696	+136.2	+886.3	11.5	*a*	....	....	....
700	+143.4	+492.7	11.5	11.0	11.0	— 5	— 5
701	+143.7	—417.2	14.8	13.8	....	—10	....
703	+145.4	+736.4	13.9	15.1	....	+12	....
705	+147.2	+611.2	11.5	11.0	11.2	— 5	— 3
707	+151.2	—253.5	11.2	11.2	11.1	0	— 1
708	+151.4	— 98.5	9.6	9.1	....	— 5	....
709	+152.9	—136.4	12.3	13.4	11.4	+11	— 9
722	+179.7	—710.4	13.3	13.2	....	— 1	....
724	+183.3	—176.0	10.5	10.2	9.8	— 3	— 7
732	+209.7	—570.4	11.5	11.2	11.5	— 3	0
734	+217.7	+443.8	9.0	8.8	....	— 2	....
737	+220.2	+266.1	15.0	15.6	....	+ 6	....
740	+225.5	+841.3	13.1	*a*	....	....	....
741	+225.9	—110.5	10.0	9.6	9.2	— 4	— 8
746	+233.1	—583.8	10.8	10.0	10.0	— 8	— 8
747	+236.4	—333.4	15.0	14.5	....	— 5	....
750	+248.4	—467.1	10.8	11.0	11.3	+ 2	+ 5
755	+277.7	—348.3	14.8	14.5	....	— 3	....
757	+280.5	+666.1	10.0	10.0	10.0	0	0
759	+285.2	+108.7	15.6	14.5	....	—11	....
762	+308.1	—848.7	14.8	15.3	....	+ 5	....
767	+317.0	—193.9	13.9	13.8	....	— 1	....
772	+334.5	+869.2	13.9	*a*	....	....	....
776	+363.	+380.	16.4	15 6	....	— 8	....
778	+366.7	—216.0	13.1	12.1	11.7	—10	—14
779	+370.	+864.	15 6	*a*	....	....	....
781	+373.8	+195.5	10.8	10.6	11.0	— 2	+ 2
783	+386.9	—746.6	13.9	15.1	....	+12	....
784	+388.4	—286.0	10.8	10.6	10.9	— 2	+ 1
785	+389.7	+587.2	10.8	10.6	11.0	— 2	+ 2
786	+389.7	+684.8	13.9	*c*	....	....	....
787	+389.7	+849.3	13.3	*a*	....	....	....
789	+395.9	—245.7	14.8	15.3	....	+ 5	....
793	+414.6	—516.7	11.7	11.5	11.8	— 2	+ 1
794	+416.0	+971.9	12.5	*a*	....	....	....
795	+416.9	—776.5	12.5	12.1	....	— 4	....
797	+427.4	+172.7	15.0	*d*	....	....	....
801	+445.	—282.	13.1	*d*	....	....	....
805	+457.2	+331.9	13.9	*d*	....	....	....
806	+459.8	+780.1	11.7	*a*	....	....	....
808	+464.7	+391.2	11.9	11.8	....	— 1	....
820	+510.8	+978.9	14.2	*a*	....	....	....
822	+514.8	—306.0	10.7	10.0	10.6	— 7	— 1
824	+518.0	+922.2	12.1	*a*	....	....	....
825	+518.1	—716.6	14.2	15.1	....	+ 9	....
826	+521.0	+419.6	14.8	*c*	....	....	....
832	+537.3	—322.4	13.9	14.1	....	+ 2	....
840	+563.	—171.	15.6	*d*	....	....	....

TABLE IV. — *Continued.*

Bond No.	Δα.	Δδ.	Bond Magn.	Common Magn.	Draper Magn.	Resid. Common.	Resid. Draper.
843	+578.1	—853.6	8.6	8.3	....	— 3	....
846	+603.3	—119.1	15.0	*d*	....	....	....
847	+619.4	+634.9	13.1	*d*	....	....	....
848	+631.2	+ 60.2	9.9	9.6	9.6	— 3	— 3
855	+654.0	—989.3	11.0	10.7	....	— 3	....
859	+661.1	—577.5	14.8	*d*	....	....	....
863	+680.9	+357.8	12.5	15.1	....	+26	....
865	+683.1	+957.0	13.9	*a*	....	....	....
873	+707.0	+981.7	11.9	*a*	....	....	....
875	+709.4	+839.4	14.8	*a*	....	....	....
889	+801.6	—258.2	11.3	11.5	....	+ 2	....
893	+815.0	+228.3	13.1	15.1	....	+20	....
899	+861.3	+744.6	14.2	*a*	....	....	....
904	+884.1	—134.0	14.2	*d*	....	....	....
905	+892.8	—918.3	7.8	8.0	....	+ 2	....
908	+901.2	+714.9	13.2	*a*	....	....	....

The light of the brightest stars is derived from Table V., as will be described below. The letter *a* is substituted for the magnitude in the case of stars outside the limits of the photograph; *b* is used to designate stars in the central nebulosity, which are therefore not easily distinguished; *c* indicates stars visible on G, but not on F; and *d*, those not contained on either F or G. The sixth column gives the magnitude derived from the photograph of Dr. Draper. The light of each star in a copy of E was found by Argelander's method, and also by arranging the stars in a sequence. The mean of these magnitudes is that here employed. The last two columns give the residual, expressed in tenths of a magnitude, found by subtracting the Bond magnitude from the photographic magnitudes given in the two previous columns.

A list of the stars visible in other copies of E is given by Professor Holden in Table A, on page 228 of his Memoir. Three of these stars, Nos. 685, 708, and 734, are too bright for satisfactory measurement in E, and two others, 435 and 863, are not visible either in E, D, or C. No. 497 is apparently omitted by mistake in Professor Holden's list. For five stars, 580, 650, 653, 663, and 709, the results derived from E and F are discordant. The first three of these are the faintest stars measured on E, and the last two are so surrounded by nebulosity that the measure is difficult. Were the first three stars as faint as F would indicate, it would be impossible to see them on E. They are certainly visible on D, and 653 on C also. No. 663 is brighter than 681 in E, as bright in D, and not seen in C; in F and G it is much fainter than 681.

TABLE V.

Bond No.	Bond Magn.	A.	B.	E.	E′.	F.	F′.
905	7.8	....	....	....	....	8.0	....
843	8.6	....	....	....	....	8.3	....
467	8.7	....	....	9.4	9.3	8.8	....
685	8.3	8.7	8.8	....	....	8.8	....
734	9.0	....	9.2	....	....	8.8	....
708	9.6	9.0	9.0	....	....	9.1	....
570	9.4	9.4	9.5	9.4	9.2	9.4	9.4
554	9.0	....	....	9.3	9.6	9.4	....
741	10.0	9.3	9.4	9.2	....	9.7	9.5
848	9.9	....	9.7	9.7	9.6	9.7	9.6
505	9.6	....	9.7	9.6	9.6	9.7	9.5
757	10.0	....	....	10.0	10.1	10.2	9.7
724	10.5	9.7	9.7	9.8	9.8	10.5	9.8
746	10.8	....	....	10.0	9.9	....	10.0
523	10.1	10.0	10.3	10.0	10.0	10.5	9.8
669	9.4	9.9	10.0	10.1	10.3	....	10.4
685	10.5	10.1	10.6	....	10.7	....	10.9

The brightest stars in the nebula are compared in Table V. The first and second columns give the Bond number and magnitude. The columns headed A, B, E, and F give the magnitudes derived from those photographs respectively by the method of sequences. The results derived from E and F by the method of Argelander are given in the columns headed E′ and F′. The mean values of E and E′, and of F and F′, are given in Table IV.

One of the most important applications of the determination of photographic magnitudes is to the measurement of the colors of the stars. The rays affecting the photographic plate have in general a less wave-length than those to which the eye is most sensitive. It therefore follows that a reddish star, that is, one in which the rays of great wave-length predominate, will appear relatively too faint in the photograph. The residuals in the last columns of Table IV. will then be positive. A bluish star is similarly indicated by a large negative residual. These residuals form a convenient measure of the color of the stars. In most stars the difference in color is due to slight differences in the relative intensities of the blue and red rays. Until the law defining the relation of the intensity to the wave-length is known, a single number serves to describe the principal cause of the color. Of course in the case of stars in which a large part of the light is concentrated in bands or lines, the residuals will not be directly comparable with those of other stars. Even here, however, this test may be advantageously employed to compare stars of the same class, as, for instance, those of the third type of Secchi.

TABLE VI.

Red Stars.						Blue Stars.					
Bond No.	Bond Magn.	A.	B.	B—A.	Resid.	Bond No.	Bond Magn.	A.	B.	B—A.	Resid.
508	12.3	14.5	15.1	+.6	+2.5	378	14.8	13.8	13.8	0	—1.0
558	10.7	11.7	11.5	—.2	+0.9	402	12.3	11.3	11.4	+.1	—0.9
580	12.3	14.5	14.3	—.2	+2.1	435	13.1	12.0	12.0	0	—1.1
650	13.1	15.2	15.1	—.1	+2.1	573	13.9	12.5	12.3	—.2	—1.5
663	11.7	14.8	14.8	0	+3.1	657	13.1	12.0	12.1	+.1	—1.1
703	13.9	15.1	15.1	0	+1.2	680	13.9	11.6	12.0	+.4	—2.1
709	12.3	13.4	13.4	0	+1.1	681	14.8	13.2	13.2	0	—1.6
783	13 9	15.1	15.1	0	+1.2	701	14.8	13.8	13.5	—.3	—1.2
863	12 5	15.1	15.1	0	+2.6	759	15.6	14.5	14.8	+.3	—1.0
893	13.1	15.1	15.1	0	+2.0	778	13.1	12.1	11.9	—.2	—1.1

The first part of Table VI. contains the stars in which the residual equals or exceeds one magnitude. The first three columns give the Bond number and magnitude and the photographic magnitude, taken from the first, fourth, and fifth columns of Table IV. The photographic magnitude was determined a second time to see if the large residual was due to error. The results are given in the fourth column of Table VI. The difference in the two measures is given in the next column, and in the last column the residual found by subtracting the second column from the mean of the third and fourth columns. The second part of Table VI. gives the corresponding values for the blue stars in which the residual has a negative value exceeding one magnitude.

The first part of Table VII. contains the stars given in the Bond Catalogue not contained in the photograph, and accordingly marked *d* in Table IV. As the faintest stars visible in the photograph have a photographic magnitude of about 15.0, it follows that a slight redness of the stars in Table VII. would account for their absence in the photograph. The stars marked *c* in Table IV. are Bond 367, 443, 786, and 826; although not visible in F, they were detected in G.

The second part of Table VII. contains the stars which are visible in both the photographs F and G, but are not given in the Bond Catalogue. The successive columns give a current number, the approximate difference in right ascension and declination from θ' *Orionis*, and the photographic magnitude.

Many more objects which cannot be distinguished from stars are visible on either F or G, but not on both. After completing this list, it was compared with the map of the Earl of Rosse (Phil. Trans., 1868, Pl. III.). Stars appear on this map which are moderately near Nos. 4 and 11, but none are near any of the other stars in the second part

TABLE VII.

Bond No.	Bond Magn.	No.	Δα.	Δδ.	Magn.
329	14.2	1	—464	— 424	14.8
332	14.8	2	—370	— 122	13.8
419	14.2	3	—143	— 611	13.5
532	14.2	4	—120	— 515	13.5
552	14.9	5	— 62	— 514	13.8
615	14.2	6	— 17	—1011	14.5
641	14.8	7	— 9	— 592	13.8
797	15.0	8	+ 34	— 960	14.8
805	13.9	9	+ 42	— 854	15.1
840	15.6	10	+ 77	— 480	12.7
847	13.1	11	+316	— 639	13.0
904	14.2				

of Table VII. None of them are given in the list prepared by Lord Rosse of the stars not contained in the catalogue of Struve (Phil. Trans., 1868, p. 59). A comparison with the map of Mr. Common (Monthly Notices, XLIII. 256) showed that Nos. 10 and 11 were already given there. Mr. Common's stars *nf.* 690 and *np.* 750 are not visible on G, although the first of them is well shown on F. The stars near Bond 685 and 741 were not measured on account of the nebulous light with which they are surrounded. Their presence in G is somewhat doubtful. Until the remaining stars are actually seen, we may infer that they are too faint to be visible to the eye, and that our only evidence of their existence is by means of the photographic plate. These stars are also probably of a bluish color. As the number of stars is nearly the same in the two parts of Table VI., we may infer that for white stars the limiting magnitude for the photograph does not differ much from that for the eye.

The agreement of the results given on page 408 is hardly a fair test of the errors of measurement. A better indication is afforded by the repetition of the measurement of the red and blue stars in Table V. The average difference in the results is .14 of a magnitude, which indicates a probable error of each of about .08. The two measures of E by Argelander's method and by sequences give for the 35 stars compared by both methods an average deviation of .20, or a probable error of .12. Forty stars are common to E and F. Omitting the five which are stated on page 413 to be discordant, the average difference in the two magnitudes of the remaining thirty-five is .27. The probable error of each, if they are equal, is .16.

INVESTIGATIONS ON LIGHT AND HEAT, MADE AND PUBLISHED WHOLLY OR IN PART WITH APPROPRIATION FROM THE RUMFORD FUND.

XIX.

BRIEF CONTRIBUTIONS FROM THE PHYSICAL LABORATORY OF HARVARD COLLEGE, UNDER THE DIRECTION OF PROFESSOR JOHN TROWBRIDGE.

RELATION BETWEEN SUPERFICIAL ENERGY AND THERMO-ELECTRICITY.

BY CHARLES BINGHAM PENROSE.

Communicated by Professor Trowbridge, June 11, 1884.

WHEN two media which do not mix are in contact, the particles near the surface have more energy than similar particles in the interior of the media. It is probable that this increase of energy is sensible only within a distance of a thousandth of a millimeter from the surface.

The result of this difference of energy is to render the surface of contact of the media as small as possible. This is seen in Plateau's experiment upon a mixture of oil in alcohol and water.

When the area of the surface is increased in any way the surface energy is increased, and work can be done in the contraction of the surface. The surface behaves exactly as if a tension equal in all directions existed at every point of it. In discussing surface energy it can therefore be considered in two ways. It can be considered as part of the internal energy of the body; and in this case to the internal energy that is generally understood in thermodynamics must be added a term which shall be proportional to the surface, and also a function of the temperature. Or it may be introduced into the equations of the external work: and in increasing the surface it can be said that work is done against superficial tension in the same way that work is done against an external pressure.

The numerical value of the surface energy per unit of area is equal to that of the surface tension per unit of length.

Since the superficial tension depends not only upon the body itself, but also upon the substances in contact with the body, and since work done by, or against, superficial tension depends not merely upon the initial and final states of the body, but upon the manner of passing

from one state to the other, it is probably best to introduce surface energy into the equations of the external work.

Let the state of any body be represented as a function of the two independent variables x and T, — where T is the absolute temperature. If the body is an homogeneous solid, its mechanical state is represented as a function of six independent variables. The equations, however, deduced by considering only the variations of x and T can be extended to the case of a solid by adding five other equations of the same form.

When the body undergoes any small transformation, the quantity of heat absorbed — expressed in mechanical equivalents — is:

$$d\,Q = a\,d\,x + b\,d\,T. \qquad \text{(A.)}$$

The coefficient "a" depends upon the external and the internal works. It is the mechanical equivalent of the latent heat relative to the variable x. $\frac{b}{J}$ represents the specific heat of the body for a constant mechanical state.

The external work is done against superficial tension and external pressure: hence "a" depends upon these two quantities.

The value of the external work in the above transformation is:

$$d\,W = p\,d\,x + S\,d\,x. \qquad \text{(B.)}$$

S is a function of the superficial tension and of the shape of the body. The work done against superficial tension is equal to the coefficient of capillarity — or the coefficient of superficial energy — into the increment of area. Let $k =$ the coefficient of capillarity, and let

$$\frac{d\,A}{d\,x} = f\,(x),$$

where A equals the area of the surface of the body. Then for S may be substituted

$$S = k\,f\,(x).$$

Let F represent the total energy of the body:

$$d\,F = a\,d\,x + b\,d\,T + p\,d\,x + S\,d\,x. \qquad \text{III.}$$

For any closed cycle the total variation of F is zero. The value of an increment of F depends merely upon the initial and final states of the body. $d\,F$ is therefore an exact differential.

$$\frac{d\,(a + p + S)}{d\,T} = \frac{d\,b}{d\,x} \qquad (a.)$$

If the body is supposed to pass through a reversible cycle,

$$\int \frac{d\,Q}{T} = O;$$

$$\therefore \int \frac{a\,d\,x + b\,d\,T}{T} = O. \qquad \text{IV.}$$

Equation IV. only holds if all the steps of the transformation are of a perfectly reversible character, and if the body is finally brought back to its primitive state in every respect. That the part of the transformation depending upon changes in the superficial energy may be considered reversible is shown by the following example:—

I. Let a soap film be stretched, at temperature T, to area A.
II. Let it then be cooled to temperature $T - d\,T$.
III. Let it then contract at temperature $T - d\,T$ to its original mechanical state.
IV. Let it then be heated to temperature T.

Every step of this process is obviously reversible, and the body is finally brought back to its original state in every respect. The work done by the film is equal to that which would have to be done upon it in order to go through the cycle in the reverse direction.

In equation IV. the expression under the integral sign must be an exact differential:

$$\frac{d}{d\,T}\left(\frac{a}{T}\right) = \frac{d}{d\,x}\left(\frac{b}{T}\right);$$

substituting from (a),

$$T\frac{d\,a}{d\,T} - a = T\frac{d\,b}{d\,x} = T\left[\frac{d\,a}{d\,T} + \frac{d\,p}{d\,T} + \frac{d\,S}{d\,T}\right];$$

$$\therefore \frac{d\,p}{d\,T} + \frac{d\,S}{d\,T} = -\frac{a}{T}.$$

Since $S = k\,f\,(x)$,

$$\frac{d\,k}{d\,T} = -\frac{1}{f\,(x)}\left[\frac{a}{T} + \frac{d\,p}{d\,T}\right]. \qquad (b.)$$

This equation gives the variation of the coefficient of capillarity with the temperature. The experiments of Wolff on the ascent of water in capillary tubes give:

$$k = 76.08(1 - 0.002\,T + 0.00000415\,T^2),$$

for a tube .02346 cm. in diameter. And

$$k = 77.34(1 - 0.00181\ T),$$

for a tube .03098 cm. in diameter.

The equation may also be written:

$$\frac{d\,p}{d\,T} = -\frac{d\,k}{d\,T} f(x) - \frac{a}{T}.$$

Thomson has shown (Proc. Roy. Soc. Edin., 1870) by considerations regarding the equilibrium between a liquid and its saturated vapor, that the pressure on the surface of the liquid depends upon the form of the surface.

In certain cases the part of the external work, $p\ d\ x$, may be considered equal to zero; the chief external work being done against superficial tension. The extension of the soap film represents such a case. Here

$$\frac{d\,k}{d\,T} = -\frac{1}{f(x)}\left[\frac{a}{T}\right]. \qquad (c.)$$

In considering the case of the soap film mentioned on page 419, it will be seen that the work done against superficial tension in Part I. of the process is

$$2\ A\ k_T.$$

A represents the area, and k_T the value of k for temperature T.

Experiment has shown that the coefficient of capillarity in general decreases as the temperature increases. The work done in the contraction of the film — Part III. of the process — is

$$2\ A\left[k_T - \frac{d\,k}{d\,T}\,d\,T\right].$$

This exceeds the work done upon the film by:

$$-2\ A\ \frac{d\,k}{d\,T}\,d\,T.$$

Consequently, from thermodynamic considerations, a certain quantity of heat, Q, must be absorbed at temperature T, and a quantity, $Q - d\,Q$, must be evolved at temperature $T - d\,T$, and

$$d\,Q = -\frac{2\,A}{J}\,\frac{d\,k}{d\,T}\,d\,T.$$

The second law of thermodynamics gives for this case

$$\frac{Q}{T} - \frac{Q - d\,Q}{T - d\,T} = O;$$

$$\therefore\ Q\,d\,T = T\,d\,Q = -\frac{2\,A}{J}\,T\frac{d\,k}{d\,T}\,d\,T;$$

$$\therefore\ Q = -\frac{2\,A}{J}\,T\,\frac{d\,k}{d\,T}.$$

This last equation is a special form of (c). It gives the quantity of heat absorbed in increasing, by A, the area of a film at constant temperature T. The application of Carnot's cycle to this special case was made by Thomson. (Proc. Roy. Soc., IX. 255.) It is obvious that the latent heat of extension of unit of area is equal to the absolute temperature into the decrement of superficial tension per degree of temperature.

Equation (c) may be written:

$$a = -\,T f(x)\,\frac{dk}{d\,T}.$$

From this form it is obvious that, if $\frac{d\,k}{d\,T}$ is minus, there must be an absorption of heat when x is increased, and an evolution when x is diminished.

Experiment has shown that the surface energy between two media is a function not only of the temperature, but also of the difference of electrical potential across the surface. Faraday observed that a large drop of mercury, in contact with dilute sulphuric acid, changed its form when connected with the electrode of a battery. And Lippmann * has made a series of experiments upon the relation between superficial tension and electrical phenomena in the case of mercury in contact with various substances.

The results of Lippmann's experiments may be summed up as follows: —

I. The superficial tension between two liquids is not a specific constant depending merely upon the nature of the substances in contact. The superficial tension is a function of the difference of electrical potential between the two liquids; and for every value of the difference of potential, there is one, and only one, value of the superficial tension.

* Annales de Chimie et de Physique, 1875 and 1877.

II. In the case of mercury — at least in contact with any liquid — the superficial tension is independent of the chemical constitution of the liquid, and depends only upon the difference of potential at the surface. The chemical constitution of a liquid affects the superficial tension only by changing the difference of potential. The experiments of Bloudlot* make it probable that this law can be extended to the case of platinum.

III. When, by mechanical means, the surface of a liquid is deformed, the difference of potential at this surface varies in such a direction that the change in superficial tension developed by the variation of potential is opposed to the continuation of the deformation. This agrees with Lenz's law.

IV. In the case of mercury and dilute sulphuric acid, the superficial tension increases nearly proportionally to the difference of potential; until the difference of potential equals 0.9 Daniell. Any further increase of the difference of potential causes a diminution of the superficial tension.

The experiments of Lippmann explain the cause of the variations observed in measurements of the superficial tension. These variations were first noticed by Quincke † and were attributed by him to the presence of impurities.

Lippmann's experiments show that a close relation exists between contact electricity and superficial tension. This relation may be expressed mathematically as follows: — Let k, as before, represent the coefficient of superficial tension. S represents the area of the surface, and e the difference of potential at the surface; k is a function of e, and is of course independent of S.

If, by the action of any force, the surface is increased by dS, the work done is

$$dW = -k\,dS.$$

There is at the same time a difference of electrical potential created, the action of which is to oppose the force. An electrical separation takes place across the surface. The quantity, m, of electricity separated is a function of the surface and of the difference of potential:

$$m = \phi\,(S\,e),$$

$$dm = X\,dS + Y\,de.$$

* Journal de Physique, tom. x.

† Ann. de Poggendorff, vol. cxxxix., 1870.

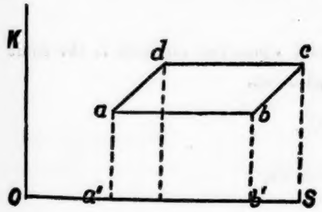
The consideration of this case may be simplified by a method analogous to that employed in thermodynamics.

In the figure below, let abscissæ represent areas of the surface, and ordinates represent tension per unit-length. Any transformation due to changes in the area and superficial tension of the surface may be represented by a line on the diagram. The work done during the transformation "*a b*" is equal to the area *a a' b' b*. The area of any closed curve gives the work done during the cyclical process represented by the curve. Since the superficial tension is a function of the difference of potential across the surface, the work will be a function of the difference of potential.

By keeping the liquids on each side of the surface in contact with electrified bodies the difference of potential can be made to vary as we please. The deformation of the surface, due to any force, may be made to take place at constant, or at variable potential.

A special form of cyclical process may be arranged such that the transformations take place only in two ways. In one way the liquids are kept in contact with conductors of infinite capacity and constant potential; in the other way they are insulated. The line representing a transformation according to the first way is parallel to *O S*, and electrical energy must either leave or enter the liquids. For in order to keep the difference of potential constant, when it tends to increase, electrical energy must leave the surface of contact of the liquids; and when the difference of potential tends to diminish electrical energy must be furnished to the surface.

As in thermodynamics any cycle can be considered to be made up of isothermal and isentropic lines, so in the present case any cycle may be considered to be made up of lines of constant potential, and lines of variable potential.



Let the cycle in the figure be composed of two lines of constant potential, and two lines of variable potential.

Along the line *a b* work is done in increasing the area of the surface. By III. of Lippmann's results, the difference of potential tends to increase, and k tends to increase. To keep the difference or potential constant, electrical energy, E_1, must leave the liquids.

Along the line *b c* work is done upon the surface; and the difference of potential and k are increased. No energy of any kind is allowed to

enter or leave the liquids. Along the line $c\,d$ the surface contracts and does work at the constant increased difference of potential. The tendency of the difference of potential along $c\,d$ is to diminish, and to keep it constant electrical energy, E_2, must enter the liquids.

Along $d\,a$ the surface contracts and the difference of potential and superficial tension diminish to their original values.

The liquids, after this process, are in every respect in their primitive condition; and the difference of potential across the surface being the same, the total quantity of electricity upon the surface must be the same as at the beginning of the process.

It is obvious from Lippmann's results that the cycle is also completely reversible. Since during the cycle there is a gain of work $a\,b\,c\,d$, the electrical energy which enters the liquids must be greater than that which leaves them, and we have

$$a\,b\,c\,d = E_2 - E_1.$$

As the liquids are conductors, the only place at which a difference of potential exists, in the whole body, is at the surface of separation. The quantities of electricity entering and leaving the body, do so at this difference of potential.

Let P_1 and P_2 represent the differences of potential for the lines $a\,b$ and $c\,d$ respectively.

$\frac{E_1}{P_1}$ is proportional to the quantity of electricity Q_1 which leaves the liquids along $a\,b$.

$\frac{E_2}{P_2}$ is proportional to the quantity Q_2 which enters the liquids along $c\,d$.

Since the total quantity of electricity upon the surface is the same at the end of the process as at the beginning,

$$Q_1 = Q_2,$$

$$\therefore \quad \frac{E_2}{P_2} - \frac{E_1}{P_1} = O.$$

As any cycle may be decomposed into special cycles like the one that has been considered, we have for the most general case,

$$\int d\,E = W = -\int k\,d\,S, \qquad \text{V.}$$

$$\int \frac{d\,E}{P} = O = \int d\,m. \qquad \text{VI.}$$

The electrical cycle that has been considered would probably be found useful in the investigation of many similar problems, where electrical energy is transformed into mechanical work.

The analogy between the equations V. and VI. and those derived from the two laws of thermodynamics is very close.

The equations might have been obtained by accepting immediately the theory of the conservation of electricity.*

Since

$$dE = P\,dm = e\,dm,$$

equation IV. may be written

$$\int e\,dm = -\int k\,dS;$$

$$\therefore \int (e\,dm + k\,dS) = 0.$$

Substituting the value of dm,

$$\int (e\,Y\,de + e\,X\,dS + k\,dS) = 0.$$

As the expression under the integral sign is an exact differential,

$$\frac{d\,(eX + k)}{de} = \frac{d\,(eY)}{dS}.$$

X obviously represents the electrical capacity of unit surface at constant potential.

Y is the electrical capacity of the whole surface, as the potential varies. If C is the capacity for unit surface

$$Y = CS.$$

The last equation reduces to

$$e\,C = \frac{d\,(eX + k)}{de}. \qquad (d.)$$

From equation VI.,

$$\int dm = 0,$$

$$\int (C\,S\,de + X\,dS) = 0.$$

This expression being also an exact differential,

$$C = \frac{dX}{de}. \qquad (e.)$$

* Lippmann, Journal de Physique, tom. x.

By combining equations (e) and (d) we obtain

$$X = -\frac{dk}{de} \text{ and } C = -\frac{d^2k}{de^2};$$

and dm may be written

$$dm = -d\left[S\frac{dk}{de}\right].$$

These equations were obtained by Lippmann. They show the close relation existing between contact electricity and superficial tension. The equations contain all the results of Lippmann's experiments; and though these experiments were made only upon special substances, yet it seems probable that the conclusions can be extended to all substances.

If the electrical charge for any transformation is kept constant,

$$O = CSde + XdS;$$

$$\frac{de}{dS} = -\frac{X}{CS} = -\frac{-\frac{dk}{de}}{-\frac{d^2k}{de^2}S}.$$

From Section IV., page 422, it is seen that $\frac{dk}{de}$ is plus below a certain value of e for mercury. As the curve representing the change of k with e is concave toward e, $\frac{d^2k}{de^2}$ is minus. Hence $\frac{de}{dS}$ is plus, or below a certain limit the difference of potential increases as the area of the surface increases.

Substances which do not act chemically on each other follow Volta's tension law. In any closed circuit at uniform temperature the sum of the differences of potential between the elements of the circuit is null. From II. of Lippmann's experiments is obtained a simple method of finding the superficial tension between two liquids, which do not act chemically upon each other, when we know the superficial tension between each of these liquids and a third liquid.

Let the contact electromotive forces between AB, BC, CA, be e_1, e_2, e_3, respectively. Let k_1, k_2, k_3 be the superficial tensions corresponding to these differences of potential.

$$k_1 = \phi\,(e_1) \;\therefore\; e_1 = \phi^{-1}\,k_1.$$

Also,

$$e_2 = \phi^{-1}\,k_2 \text{ and } e_3 = \phi^{-1}\,k_3.$$

Since

$$e_1 + e_2 + e_3 = O,$$

$$\phi^{-1} k_1 + \phi^{-1} k_2 + \phi^{-1} k_3 = O;$$

$$\therefore \quad k_3 = -\phi\,[\phi^{-1} k_1 + \phi^{-1} k_2].$$

Suppose we have a vertical glass tube, the lower half containing mercury and the upper half dilute sulphuric acid. Suppose the + pole of a battery, the electromotive force of which does not exceed 0.9 Daniell, is connected with the acid, and the — pole with the mercury. The superficial tension is increased and there is a contraction of the surface. From equation (c) a quantity of heat Q is evolved:

$$Q = -T \frac{dk}{dT}\, dS.$$

If the poles of the battery are reversed there will be an absorption of heat of the same amount. If the difference of potential exceeds 0.9 Daniell the effects will be reversed.

This is completely analogous to the Peltier phenomenon on each side of a neutral point.

If the surface of separation between mercury at constant potential and dilute sulphuric acid at constant higher potential is increased by the action of any force, work is done against superficial tension, and the energy of electrical separation appears. Positive electricity is separated across the surface from mercury to acid; and the tendency of the electrical action is to oppose the force. Conversely if the energy of electrical separation disappears by the passage of positive electricity from the acid to the mercury, mechanical work is done against superficial tension by dilatation of the surface.

Suppose we have a bent glass tube of uniform bore, containing dilute sulphuric acid in the bent part, and a column of mercury in each arm A and B. Let the temperature of the meniscus at A be T, and that of the meniscus at B be $T - dT$. Let the potential of the sulphuric acid be maintained constant, by any means, and equal to V.

Let the mercury at B be put in contact with a conductor of constant potential V_1, and infinite capacity. Let the mercury at A be put in contact with a similar conductor at potential V_2.

Let these potentials be so arranged that the change in the difference of potential at B is equal and opposite to that at A.

If the difference of potential at B is increased an electrical separation takes place so as to produce a contraction of the surface. At A

the separation takes place so as to produce a dilatation of the surface. The electrical change causes an evolution of heat at B, and an absorption of heat at A.

For the present it will be assumed that the superficial tension is a function of the temperature.

The electrical works at A and B are equal and opposite.

Since, however, the superficial tensions at the two surfaces are different, the changes in the areas of these surfaces, though opposite, are not equal.

Let $d\,S_A$ equal the increment of area at A. Let $d\,S_B$ equal the increment of area at B.

The work done at A is

$$-k\,d\,S_A.$$

The work done at B is

$$-\left(k-\frac{d\,k}{d\,T}\,d\,T\right)d\,S_B.$$

Since these works are equal,

$$d\,S_A=\left[1-\frac{1}{k}\,\frac{d\,k}{d\,T}\,d\,T\right]d\,S_B.$$

The quantity of heat absorbed during the expansion $d\,S_A$ is

$$\begin{aligned} Q_A &= -\,T\frac{d\,k}{d\,T}d\,S_A, \\ &= -\,T\frac{d\,k}{d\,T}\left[1-\frac{1}{k}\,\frac{d\,k}{d\,T}\,d\,T\right]d\,S_B. \end{aligned}$$

The quantity of heat given out during the contraction $d\,S_B$ is

$$\begin{aligned} Q_B &= (T-d\,T)\left[\frac{d\,k}{d\,T}\right]d\,S_B, \\ &= T\frac{d\,k}{d\,T}d\,S_B-d\,T\frac{d\,k}{d\,T}d\,S_B. \end{aligned}$$

$$\therefore\quad Q_A+Q_B=\left[\frac{T}{k}\left(\frac{d\,k}{d\,T}\right)^2 d\,T-d\,T\,\frac{d\,k}{d\,T}\right]d\,S_B.$$

As long as $\frac{d\,k}{d\,T}$ is minus, the right-hand member of this equation is essentially minus, and there is consequently more heat absorbed than evolved.

If the direction of the change of potential were reversed, the above expression would represent the excess of heat evolved at the hot surface over that absorbed at the cold surface.

In the case under consideration a difference of potential is created, and an electrical displacement takes place throughout the tube. Let e equal the total electromotive force, and dm the displacement.

Let R equal the electrical resistance.

$$e\,dm = R\,dm^2 + (Q_A + Q_B)\,J.$$

Let

$$(Q_A + Q_B)\,J = d\theta \,.\, dS_B.$$

We have seen that

$$dm = -X\,d\,S_B,$$

for a constant difference of potential;

$$\therefore \quad e\,dm = R\,dm^2 - d\theta \,.\, \frac{1}{X}\,dm;$$

$$\therefore \quad dm = \frac{e + \frac{d\theta}{X}}{R}.$$

This equation shows that the electromotive force e is supported by an electromotive force $\frac{d\theta}{X}$. This electromotive force is due to the difference of temperature between A and B, and is maintained by the absorption of heat at the warmer surface.

Let this electromotive force be represented by dE;

$$X\,dE = d\theta.$$

From the definition of $d\theta$,

$$\frac{d\theta}{dT} = \left[\frac{T}{k}\left(\frac{dk}{dT}\right)^2 - \frac{dk}{dT}\right] = X\frac{dE}{dT}.$$

We have seen that $\frac{dk}{dT}$ is of the form,

$$\frac{1}{f(x)}\left[\frac{a}{T}\right],$$

$$\therefore \quad \frac{dE}{dT} = \frac{a}{f(x)\,X}\left[\frac{a}{k\,f(x)} - 1\right]\frac{1}{T}.$$

This equation shows that the variation of the secondary electromotive force — the electromotive force peculiar to the arrangement — with the temperature, is inversely proportional to the temperature.

The analogy between this thermo-electromotive force, which is caused by a change in the superficial energy, and the electromotive force of an ordinary thermo-electric circuit, is thus very close. It will be remembered that for a thermo-electric circuit

$$\frac{dE}{dT} = \frac{\pi}{T}.$$

If we accept the conclusion of Lippmann,* that the temperature alters the superficial tension only by altering the difference of potential, we can consider the superficial tension only as a function of the difference of potential, and the difference of potential as a function of the temperature.

$$\frac{dk}{dT} = \frac{dk}{de} \cdot \frac{de}{dT},$$

$$= -\frac{1}{f(x)} \left[\frac{a}{T}\right],$$

$$\therefore \frac{de}{dT} = -\frac{1}{f(x)} \cdot \frac{a}{T} \cdot \frac{1}{\frac{dk}{de}}.$$

This expression is also of the same form as the one already obtained; and shows that the variation of the difference of potential with the temperature is inversely proportional to the temperature.

In the case of mercury and sulphuric acid, $\frac{dk}{de}$ is $+$ up to a certain point, after which it is $-$. Consequently, for this case, $\frac{de}{dT}$ is $+$ up to a certain point, and is afterwards $-$. This is the same as the variation of the electromotive force of a thermo-electric circuit, on each side of a neutral point.

The cases already considered point to a close relation between superficial energy and the energy of a thermo-electric current. In the first case, however, a continuous current could be maintained only by rapid changes, or vibrations, in the surface of separation of the mercury and acid.

By considering the area of the surface to remain unchanged, and by investigating only the changes in the potential energy of the sur-

* Annales de Chimie et de Physique, 1877, p. 275.

face, caused by variations of temperature, similar results may be obtained without the aid of Lippman's experiments.

It will, for the present, be assumed that the superficial tension decreases as the temperature increases.

When any surface of constant area is heated, a certain amount of superficial energy disappears. It must be converted into some other form of potential energy. This other form of energy can be made to reappear, as heat, in the contraction of the surface. Equation (c) shows that the evolution of heat varies directly with the temperature of the surface.

If therefore we consider unit surface at temperature T, we can find the total amount of energy in the surface by making it contract to nothing at constant temperature T.

The total heat in the body upon which the surface considered exists, is

$$\int_0^T \sigma \, d\,T + T\frac{d\,k}{d\,T}\frac{1}{J},$$

where σ equals the total specific heat before the formation of the surface. When this surface disappears the total heat is diminished by

$$T\frac{1}{J}\frac{d\,k}{d\,T}.$$

The total energy is further diminished by an amount equal to the potential energy of superficial tension of the surface.

The total potential energy of any surface is, therefore, equal to the potential energy of superficial tension plus another form of potential energy, which appears as heat in the contraction of the surface. Hence, what we have previously understood as superficial energy is but a part of the total energy of any surface.

Let k equal the superficial tension at temperature T. Let q equal the mechanical equivalent of the heat evolved in the contraction of unit surface to nothing. Let P equal the total energy of unit surface.

$$P = k + q. \qquad (f.)$$

The following consideration is based upon the fact that this value of P for any surface is independent of the temperature. This can easily be seen by considering the cycle on page 419. If k_1 and q_1 are the values of k and q at the higher temperature, and k_2 and q_2 their values at the lower temperature,

$$k_2 - k_1 = q_1 - q_2,$$
$$\therefore \quad k_1 + q_1 = k_2 + q_2 = P.$$

The electrical separation at a hot surface is, in general, greater than that at a cold surface. Consequently, when the temperature of a surface is raised, a certain amount of potential energy of electrical separation appears. At the same time a quantity of potential energy of superficial tension disappears. Moreover, as the surface contracts to nothing, potential energy of electrical separation disappears and the energy of heat appears. If the surface is kept constant, and no energy is allowed to enter or leave it, the electrical energy developed by a change of temperature must be equal to the decrease in k, and to the increase in q of equation (f).

The energy of electrical separation for an increment of temperature $d\,T$ is consequently

$$-\frac{d\,k}{d\,T}\,d\,T,$$

for unit surface.

If the two sides of the surface are electrically connected, the electrical separation disappears. Nevertheless the value of P must remain constant; and the energy which leaves the surface must be replaced by an equal amount of energy which can only be derived from the heat at the surface.

Consider that the two ends of a horseshoe-shaped platinum bar, $A\,B$, are surrounded by a glass tube, $A\,C\,B$, containing dilute sulphuric acid. The areas of the surfaces of contact of platinum and acid are constantly equal to unity.

In the beginning let the whole apparatus be at temperature T. The total surface energies of A and B are equal, and consist of two parts which are respectively equal. The potential energy of superficial tension is the same at each surface; and the electrical energy is the same, since there is electrical equilibrium.

Let the temperature of A be increased by $d\,T$.

The total surface energy at A is still unchanged — aside from the mere increase of heat — but the components of the total energy are different. There is less energy of superficial tension, and greater energy of electrical separation. Since the circuit is composed of conductors there will be an establishment of electrical equilibrium; and the electricity separated at A from platinum to acid, will flow toward the right. To maintain the value of P at the surface A constant, heat must be absorbed, and a steady current will thus be produced.

Moreover, it is obvious that heat will be evolved at the surface B. For the heat evolved when the surface contracts to nothing is due to the disappearance of the energy of electrical separation; the electricity flowing back in a direction opposite to that in which it was first separated.

Consequently, if electricity is separated from platinum to acid, heat will be evolved when it flows from acid to platinum.

The energy of electrical separation that takes place at any instant is

$$-\frac{dk}{dT}\,dT.$$

The current strength into the electromotive force equals the electrical energy, and this is maintained by a disappearance of heat which must be proportional to

$$\frac{dk}{dT}\,dT\,\Sigma\,dm\,,$$

$\Sigma\,dm$ being the total quantity of electricity separated in unit time. A current of unit strength would consequently absorb an amount of heat:

$$-\frac{dk}{dT}\,dT\,M = \theta\,d\,T.$$

The arrangement considered forms a reversible thermodynamic engine. For small currents we can therefore consider the heat absorbed as proportional to the first power of the current strength.

The heat absorbed by a current dm is

$$\theta\,dm\,d\,T.$$

The energy of the current must equal the heat absorbed:

$$de\,.\,dm = \theta\,dm\,.\,d\,T,$$

$$\therefore\quad \frac{de}{dT} = \theta = -\frac{dk}{dT}\,M.$$

From equation (c.)

$$\frac{de}{dT} = -\frac{1}{f(x)}\left[\frac{a}{T}\right]M = \frac{\varphi}{T}.$$

For a circuit in which the temperatures of the junctions differ by a finite amount,

$$e = \int_{T_0}^{T}\frac{\phi}{T}.$$

The expression ordinarily obtained for the electromotive force of a thermo-electric circuit is

$$E = \int_{T_0}^{T} \frac{\pi}{T}.$$

The only assumption made in obtaining this equation was that the heat effects obey the two laws of thermodynamics.

It is thus seen that the same form of fundamental equation can be obtained in an entirely different way, by considering the energy of a thermo-electric current as part of the energy which resides upon every surface.

The last case is, in every respect, identical with the ordinary thermo-electric circuit between a solid and liquid. And if the results of Lippmann are accepted it has been shown that even the existence of neutral points can be explained.

If, as Maxwell says, there is for all bodies a coefficient of superficial energy, the energy of every thermo-electric circuit may be accounted for by changes in the potential energy of superficial tension.

XX.

ON THE SEPARATION OF TITANIUM AND ALUMINUM, WITH A NOTE ON THE SEPARATION OF TITANIUM AND IRON.

By F. A. Gooch.

Communicated May 13, 1885.

In attempting to separate titanium and aluminum it is usual to resort to that method which depends upon the action of the slightly acid solution of the sulphates when submitted to prolonged boiling. The faultiness of this method, however, becomes apparent when solutions of aluminum and titanium are compared as to behavior under the conditions. To secure the complete precipitation of titanium the excess of sulphuric acid must be kept small, while to prevent the deposition of alumina the acid must be more than enough to dissolve the same amount freshly precipitated as hydrate, in the cold. Thus, upon boiling solutions containing the equivalent of 0.06 grm. of titanic oxide, 2.5 grm. of free sulphuric acid, beside alkaline sulphates, in 800 cm.^{3} of water, it was found that at the end of an hour 0.003 grm. of titanic oxide in one case, and 0.006 grm. in another experiment, had escaped precipitation; but that, when the solution of titanium had first been precipitated by ammonia and then made just acid by sulphuric acid, every trace of dissolved titanium was thrown out on boiling. The experiment, on the other hand, of boiling a gram of alum — roughly speaking 0.1 grm. of alumina — in 800 cm.^{3} of water shows almost immediately the deposition of some alumina, and the same thing happens when the alumina is first precipitated by ammonia and then dissolved by just enough sulphuric acid to effect the solution. The difficulty of so adjusting the acidity of the solution that no alumina shall be deposited and no titanium held up, is obvious. Test paper is of no aid in the case, since the reaction of alum itself and aluminic sulphate is acid. Under the circumstances it is hardly surprising that Knop* should revert from the troublesome, and only under remote con-

* Jahrb. f. Min. 1876, p. 756; Zeit. f. Kryst. u. Min., i. 58.

ditions more exact, method of separation by boiling to the convenient but indubitably inaccurate process of parting by the use of sodic hydrate. Knop employs both the dry and the wet method, — the fusion of the oxides in sodic hydrate, and the treatment of the salts in solution with sodic hydrate in excess; but both had long before been generally discarded, and the single experiment of acidulating the alkaline filtrate from a precipitate obtained by the treatment of a pure titanium salt according to either mode, and then making alkaline with ammonia, is enough to prove their worthlessness.

In an endeavor to secure a better means of separating titanium from aluminum I have followed two lines of experimentation; — the one based upon the observation that, under properly controlled conditions, titanium is completely precipitated and alumina held in solution when an alkaline orthophosphate, strongly acidified with formic acid, is added to the solution of salts of these elements; the other, upon the solubility of alumina and the insolubility of titanic hydrate in sufficiently strong boiling solutions of acetic acid. Two preparations of titanium were used as test material in the course of the work; — the solution of the fusion in sodic bisulphate of the hydrate precipitated by ammonia from the fluoride of titanium and potassium itself made from rutile and carefully purified by recrystallization; and the solution obtained by treating the carefully prepared double fluoride with sulphuric acid, evaporating to dryness, redissolving in sulphuric acid and diluting with water. The second mode of preparation is the better, because the amount of alkaline sulphate present in the test solution is much smaller. At first, the strength of the solution was fixed by precipitating weighed amounts by ammonia, carefully washing, igniting and weighing the precipitate; but in the course of the work it became plain that the precipitation by means of ammonic acetate, or by ammonia with the subsequent addition of acetic acid in distinct excess, yielded more precise results. On this account, therefore, the determinations of the standard of the solutions employed in the later work were made by the acetic acid process, and the determinations by ammonia were corrected to correspond. In some of the experiments bearing upon this point, the results of which are given in the figures below, precipitations by ammonia were made in the cold and the liquid then heated to boiling; in those in which acetic acid was used just in excess, this reagent succeeded the ammonia at once, and the boiling followed; when precipitation was effected in presence of large amounts of acetic or formic acid, the acid was added in the amount intended, sodic acetate in quantity more than that necessary to decom-

pose the sulphates present was introduced, and the clear solution heated to boiling, and kept boiling for a minute or two. The acetic acid employed was the C. P. article of commerce, and contained thirty-five per cent of absolute acid. The amounts of it used — 20%, 30%, 40%, 50% by volume — correspond to 7%, 10.5%, 14%, 17.5% of absolute acid. The formic acid contained twenty-seven per cent of pure acid, and when it is said that there was in solution 5.4% of it, the absolute acid is meant; but it was the weaker acid, to the amount of 20% of the entire volume, which was actually used. The experiments were made in sets, and so appear in the record, in consequence of changes (due to slight depositions from time to time) in the strength of the test solution, which necessitated redeterminations of standard.

	Weight of Solution.	TiO_2 found.	TiO_2 in 50 grm.	Mode of Precipitation.
(1)	52.7370 grm.	0.3177 grm.	0.3012 grm.	By ammonia.
(2)	52.7610 "	0.3180 "	0.3012 "	
(3)	52.7620 "	0.3076 "	0.2912 "	By ammonia and excess of acetic acid.
(4)	41.8010 "	0.2436 "	0.2914 "	
(5)	52.9420 "	0.3381 "	0.3193 "	By ammonia.
(6)	53.0200 "	0.3384 "	0.3191 "	
(7)	10.6300 "	0.0667 "	0.3137 "	By acetic acid 7% by volume.
(8)	10.6960 "	0.0671 "	0.3137 "	
(9)	21.1030 "	0.1285 "	0.3044 "	By ammonia.
(10)	21.1480 "	0.1290 "	0.3049 "	
(11)	21.0810 "	0.1248 "	0.2960 "	By acetic acid 14% by volume.
(12)	21.1670 "	0.1259 "	0.2974 "	
(13)	21.0620 "	0.1270 "	0.3015 "	By ammonia.
(14)	21.2310 "	0.1279 "	0.3012 "	
(15)	10.4370 "	0.0617 "	0.2956 "	By acetic acid 10.5% by volume.
(16)	10.6590 "	0.0629 "	0.2950 "	
(17)	10.4870 "	0.0618 "	0.2946 "	By acetic acid 14% by volume.
(18)	10.8820 "	0.0637 "	0.2940 "	
(19)	10.4700 "	0.0615 "	0.2938 "	By formic acid 5.4% by volume.
(20)	10.7410 "	0.0627 "	0.2919 "	
(21)	52.3960 "	0.3396 "	0.3230 "	By ammonia.
(22)	52.4140 "	0.3378 "	0.3222 "	
(23)	52.6350 "	0.3340 "	0.3262 "	
(24)	52.5600 "	0.3372 "	0.3208 "	By acetic acid in distinct excess.
(25)	52.4830 "	0.3366 I "	0.3207 "	
		0.3363 II "	0.3204 "	
(26)	52.3700 "	0.3348 "	0.3196 "	By acetic acid 17.5% by volume.
(27)	52.6420 "	0.3374 "	0.3205 "	

It will be noticed in the examination of these figures that parallel determinations usually agree very closely. The amounts of titanic oxide indicated by those experiments in which the precipitation was made by ammonia, are much in excess of those in which acetic acid was added subsequently. Thus the difference between (1), (2) and (3), (4) amounts to more than three per cent of the total amount of the former; that between (5), (6) and (7), (8), to a little less than two per cent; that between (9), (10) and (11), (12), to about two and a half per cent; and a correction of more than two per cent must be applied to (13), (14) to bring them to correspondence with (15), (16), (17), (18). The difference between (21), (22), (23) and (24), (25), (26), (27) is about one per cent, and the smallness of this figure in comparison with the differences previously noted is apparently explicable by the fact that the solution of titanium employed in the last determinations was prepared by the second of the methods mentioned above, and carries a smaller amount of alkaline sulphate. The tendency of titanic hydrate to include the sulphates of the alkalies is not strange in view of the well-known conduct of aluminic hydrate under similar circumstances, but the amount thus held is rather surprising. The experiments in which different proportions of free acid were introduced go to show, very strikingly, that, if acetic acid exerts any solvent action whatever upon the precipitate thrown down by boiling the acetate, that action is very slight. Thus, between the mean of (24), (25) and that of (26), (27), — the one set precipitated by ammonia and treated before boiling with just a distinct excess of acetic acid, the other pair thrown out of a large volume, 700 $cm.^3$, one half of which was acid of 35% strength, by boiling, — we find a difference of but 0.0007 grm., and between the mean of (15), (16) and that of (17), (18), the difference (magnified five times by reference to 50 grm. portions) is 0.0010 grm. In (25), too, we have an experiment in which the weighed precipitate was fused in sodic carbonate, dissolved, and again precipitated as before and weighed, the two weights differing by 0.0003 grm. Moreover, the filtrates from the precipitates thrown out in presence of an excess of acetic acid, when neutralized with ammonia, failed invariably to show the smallest precipitate, and in direct experiments upon the sensitiveness of the reaction it was found that on the addition of 0.0005 grm. of titanic oxide in solution to 100 $cm.^3$ of 35% acetic acid carrying a little sodic acetate a distinct precipitate appeared almost immediately on boiling. It is plain, therefore, that so far as concerns the purpose in hand the insolubility of the titanium precipitate in acetic acid may be taken as absolute. The

small apparent losses to be observed in some of the determinations in which a large excess of acetic or formic acid was employed, are probably explicable by the tendency of the precipitate to change its consistency as the amount of free acid increases, and, in very acid solutions, to show an inclination to adhere in small amounts, but quite persistently, to the vessel in which precipitation takes place. The adherent precipitate may be dislodged with ease by putting a little hydrochloric acid into the beaker to which the precipitate adheres, covering and heating gently so that the acid volatilized may condense upon the walls of the beaker and again run down. By then rubbing the walls of the beaker a little and adding ammonia in excess, the trace of residual titanium is completely recovered. This method of recovery was applied in (26) and (27).

In preliminary experiments upon the first of the methods which seemed to promise a separation of titanium and aluminum, it was found that the precipitation of titanium by an alkaline orthophosphate is complete in the presence of a large amount of acetic or formic acid, and that, in the cold, and under conditions otherwise properly controlled, aluminic phosphate fails to appear. To hold up the alumina by means of acetic acid requires some care in the adjustment of the acid and phosphate, and to redissolve the precipitate once formed is a matter of considerable difficulty. Thus, to clear the solution of a precipitate produced by 1.5 grm. of the phosphate of soda and ammonia upon 0.1 grm. of alumina, it was necessary to dilute the liquid to a volume of 250 $cm.^3$, and add acetic acid until there was in the solution at least five per cent of absolute acid; and the addition of 1.5 grm. more of the precipitant again precipitated aluminic phosphate. Formic acid, however, is more active, and the balance between it and the precipitant not so delicate. When the proportion of three parts by weight of absolute formic acid to two parts of microcosmic salt is kept, the aluminic phosphate does not fall; and if, because of a deficiency of acid, precipitation does take place, the liquid immediately clears so soon as the proportion of acid and precipitant is restored. Formic acid, therefore, was used in the experiments about to be described. The test solution of titanium was that employed in the previous experiments (1) to (20), but, inasmuch as the error of the process had not yet been remarked, the standards were determined by precipitating by ammonia, and are therefore to be corrected. The application of a correction of two and a half per cent to the apparent weights of titanic oxide found by the ammonia process — the mean correction for (1), (2), (5), (6), (9), (10), (13), (14) —

cannot lead far away from the truth, since the difference between the maximum and minimum corrections observed amounts for the quantity of material employed in these experiments to but 0.0002 grm. Determinations of standard, original and corrected, are given in (28), (29), (30), and (31).

	Weight of Solution.	TiO_2 found.	Corrected TiO_2 in 50 grm.	Corrected TiO_2 in 50 cm.³
(28)	52.7660 grm.	0.3867 grm.	0.3572 grm.	0.3771 grm.
(29)	52.8410 "	0.3869 "	0.3569 "	
(30)	52.5380 "	0.3810 "	0.3627 "	
(31)	52.6920 "	0.3822 "	0.3627 "	

A portion of the solution, the standard of which is set by (28) and (29), was diluted to ten times its volume, and 50 cm.³ of the diluted solution were used in each of the experiments immediately following. These were made to determine whether the precipitate was definite in composition, and might be weighed as such. Precipitation was effected by a solution of microcosmic salt acidified with formic acid. The precipitates of (32) and (33) were collected on paper, that of (34) on asbestos, and all were ignited and weighed directly.

	Amount taken.	TiO_2 and P_2O_5 found.	TiO_2 by Standard.	P_2O_5 by Difference.
(32)	50 cm.³	0.0731 grm.	0.0377 grm.	0.0354 grm.
(33)	"	0.0640 "	0.0377 "	0.0263 "
(34)	"	0.0753 "	0.0377 "	0.0376 "

The phosphate obtained by Merz * by precipitating in presence of hydrochloric acid containing two molecules of TiO_2 to one of P_2O_5, requires 0.0326 grm. of P_2O_5 to 0.0377 grm. of TiO_2. It will be noticed that in two determinations the P_2O_5 is in a considerable excess of the amount demanded by this proportion, and in one, in deficiency. The idea of weighing the phosphoric anhydride and titanic oxide together was therefore abandoned.

In experiments (35), (36), (37), the titanium was present alone; in (38), (39), 2 grm. of alum were added to the solution before precipitating by means of the mixture of microcosmic salt and formic acid, 5 grm. of the former being employed to 8 grm. of the latter. The precipitates of all, excepting (35), were carefully washed, ignited, fused with sodic carbonate, and the product of fusion was dissolved in water, the insoluble titanate separated from the soluble phosphate

* Jour. prakt. Chem., xcix. 157.

by filtration and washing, ignited, again fused with a little sodic carbonate, the result of fusion dissolved in strong sulphuric acid, diluted with water, and precipitated by ammonia with the subsequent addition of acetic acid, and boiling. Experiment (35) was conducted in like manner, excepting that the sodic titanate was dissolved off the filter by means of a mixture of hydrochloric and oxalic acids, the latter destroyed by potassic permanganate (since there is danger that in presence of ammonic oxalate the titanium may not be completely precipitated by ammonia), ammonia added in excess, then acetic acid to strongly acid reaction, and the liquid boiled. This mode of treating the acid titanate is not desirable, since the titanic hydrate, if precipitated but once subsequently, retains a trace of manganese. To fuse the titanate with sodic carbonate, and then treat the melt with strong sulphuric acid, is probably the best way of getting the titanium into solution again. The test solution of (28) and (29) was employed in experiment (35), and that of (30) and (31) in the rest.

From experiments (36) and (37), together with (35), which, as has been remarked, would naturally give figures slightly too high, it appears that the method indicates with accuracy the amount of titanium present. Experiments (38) and (39) indicate that the separation from alumina is not unreasonably inexact.

	Weight of Solution.	TiO_2 found.	TiO_2 by Standard.	Error.
(35)	5.2220 grm.	0.0383 grm.	0.0373 grm.	0.0010 grm. +
(36)	5.2300 "	0.0371 "	0.0370 "	0.0001 " +
(37)	5.3840 "	0.0380 "	0.0381 "	0.0001 " −
(38)	5.2920 "	0.0367 "	0.0374 "	0.0007 " −
(39)	5.2540 "	0.0383 "	0.0372 "	0.0011 " +

The tediousness of filtration, which is a consequence of the nature of the phosphate precipitate, is the great objection to the method, and on account of it the testing was pushed no further, attention being turned instead to the second line of experimentation.

The incompleteness of the precipitation of alumina by the basic acetate process in presence of a large excess of acetic acid, suggested the attempt to hold up alumina entirely by means of a sufficient excess of acetic acid while precipitating titanium. Experiments to determine the amount of acetic acid necessary to prevent the precipitation of alumina from a boiling solution of the acetate, indicate that amounts of absolute acid in excess of five per cent by volume of the solution

are adequate to the purpose, and that the addition of sodic acetate in reasonable amounts does not sensibly affect conditions. It appears, further, that the addition of a very small quantity of titanium in solution to the clear boiling solution of alumina in acetic acid occasions at once a perceptible precipitation. Thus, 0.0005 grm. of titanic oxide in solution produced a distinct and appreciable opalescence in 500 $cm.^3$ of liquid containing 10 grm. of alum, 15 grm. of sodic acetate (about twice the amount necessary to convert the sulphate of alumina to the acetate), and seven per cent by volume of absolute acetic acid.

In respect to holding up alumina, formic acid acts like acetic acid, but more potently.

In the following experiments to test the method quantitatively, two solutions of titanium were employed; — in (40) and (41), the solution the value of which was fixed by (15) to (18); in (42) to (46), the solution whose standard was set by (24) to (27). To the cold solution of titanium containing a little free sulphuric acid together with some alkaline sulphate were added 5 grm. of alum (approximately 0.5 grm. of alumina), 20 grm. of sodic acetate, which was always more than enough to effect the entire conversion of the aluminic and titanic sulphates to acetates, acetic acid to such amount that in experiments (42), (43), (44) there should be in the solution seven per cent by volume of absolute acid, and in the remaining experiments ten and a half per cent by volume, and water to make the entire volume 250 $cm.^3$ in (40) and (41), and 400 $cm.^3$ in the rest. The clear solutions obtained in this manner were raised quickly to boiling, kept at that point for a minute, and removed from over the burner so that the precipitate might settle, — as it does almost immediately. The supernatant liquid was decanted upon a filter sufficiently porous to permit very rapid filtration,* and the precipitate added immediately thereafter, and washed with 7% acetic acid followed finally by hot water. The washed precipitate was dried, ignited, and weighed. The precipitate once upon the filter and drained becomes more compact and easily washed, and strong ignition of fifteen or twenty minutes over a good Bunsen burner, after the paper is thoroughly ashed, reduces it to a weight which neither the blast-lamp nor ignition in an atmosphere of ammonic carbonate changes.

* The paper No. 589 of Schleicher and Schüll is excellent for the purpose.

	Weight of Solution.	TiO_2 found.	TiO_2 by Standard.	Error.	
(40)	10.4910 grm.	0.0645 grm.	0.0618 grm.	0.0027 grm.	+
(41)	10.5970 "	0.0656 "	0.0624 "	0.0032 "	+
(42)	20.9520 "	0.1450 "	0.1343 "	0.0107 "	+
(43)	21.1750 "	0.1439 "	0.1357 "	0.0082 "	+
(44)	21.0250 "	0.1431 "	0.1347 "	0.0084 "	+
(45)	20.8740 "	0.1393 "	0.1338 "	0.0055 "	+
(46)	21.0570 "	0.1402 "	0.1349 "	0.0053 "	+

It is quite obvious that a single precipitation by the method used does not yield titanic oxide free from alumina. The weighed precipitate of each experiment was therefore fused with a small quantity of sodic carbonate, and the product of fusion treated in the crucible with strong sulphuric acid, which gradually with the aid of gentle heat dissolved everything completely. This solution after cooling was poured directly into 100 $cm.^3$ of cold water, and, the liquid remaining clear, ammonia was added just to alkalinity, and then dilute sulphuric acid corresponding to 2.5 grm. of pure acid. The precipitate thrown down by ammonia was gradually, but after a few minutes entirely redissolved, acetic acid was added until it amounted in terms of absolute acid to ten and a half per cent of the entire volume, 20 grm. of sodic acetate introduced, the solution boiled, and the precipitate treated as previously described. The results of this second treatment are given below.

	Weight of Solution.	TiO_2 found (II).	TiO_2 by Standard.	Error.	
(40)	10.4910 grm.	0.0624 grm.	0.0618 grm.	0.0006 grm.	+
(41)	10.5970 "	0.0623 "	0.0624 "	0.0001 "	—
(42)	20.9520 "	0.1373 "	0.1343 "	0.0030 "	+
(43)	21.1750 "	0.1385 "	0.1357 "	0.0028 "	+
(44)	21.0250 "	0.1369 "	0.1347 "	0.0022 "	+
(45)	20.8740 "	0.1357 "	0.1338 "	0.0019 "	+
(46)	21.0570 "	0.1383 "	0.1349 "	0.0034 "	+

In experiments (40) and (41), in which comparatively small amounts of titanium were employed, the separation from alumina was reasonably good after the second precipitation, but in (42) to (46) the larger quantities of titanic oxide still retained notable amounts of alumina. The precipitates of (45) and (46) were, therefore, treated again just as before, to determine the effect of a third precipitation.

	Weight of Solution.	TiO_2 found (III).	TiO_2 by Standard.	Error.	
(45)	20.8740 grm.	0.1347 grm.	0.1338 grm.	0.0009 grm.	+
(46)	21.0570 "	0.1360 "	0.1349 "	0.0011 "	+

Three precipitations left the titanic oxide of these experiments nearly free from alumina, but three such treatments involve a good deal of labor, and, moreover, it is evident that the precipitate still holds with tenacity traces of alumina. The experiment of attempting to remove residual alumina after a single precipitation, by treating the product of fusion of the precipitate in sodic carbonate with boiling water, filtering, igniting the residue, again fusing with a little sodic carbonate, and proceeding from this point to dissolve in sulphuric acid and precipitate once more as before, was therefore tried, and the result is given in the record of (47) to (50).

	Weight of Solution.	TiO_2 found.	TiO_2 by Standard.	Error.
(47)	20.8640 grm.	0.1329 grm.	0.1337 grm.	0.0008 grm. —
(48)	21.1100 "	0.1345 "	0.1354 "	0.0009 " —
(49)	20.9100 "	0.1332 "	0.1340 "	0.0008 " —
(50)	21.0020 "	0.1348 "	0.1346 "	0.0002 " +

This mode of treatment appears to remove the last traces of alumina, and yields a reasonably good separation.

It appears therefore, to recapitulate, that for the separation of titanium and aluminum either of the processes set forth in the preceding work may serve. The first, however, — which is, in brief, the treatment of the solution containing salts of the elements in question with a mixture of microcosmic salt and formic acid, in the proportion of two to three by weight, together with enough ammonic formate to take up the stronger acids, fusing the precipitate in sodic carbonate, extracting with water, fusing the residue in a small amount of sodic carbonate, dissolving in sulphuric acid and precipitating by ammonia with the subsequent addition of acetic, and boiling, — though probably fairly accurate, is, on account of the nature of the precipitated phosphate, not comparable with the second method in point of convenience. The latter process, which involves many different manipulations, — the introduction into the solution of titanium and aluminum of enough acetic acid to make from seven to eleven per cent by volume of the absolute acid, together with sufficient sodic acetate to fix all of the stronger acids in sodium salts, boiling, filtering, and washing with acetic acid of seven per cent strength, fusing the ignited precipitate in sodic carbonate, extracting with boiling water, again fusing the residue with a little sodic carbonate, dissolving in strong sulphuric acid and pouring this solution into water, neutralizing with ammonia, redissolving the precipitate in a known amount of sulphuric acid, and precipitating finally by boiling with acetic acid and sodic acetate as at

first, — and appears in the description to be long and tedious, may in reality be carried out with ease and rapidity, the operations being generally short and not of a difficult nature.

In most cases in which titanium is to be separated from aluminum, it is necessary to effect the removal of iron as well. Some experiments looking to the separation of titanium and iron, by boiling the acetates in presence of a large excess of acetic acid, were unsuccessful; for, though an excess of acetic acid amounting to eleven per cent of absolute acid in the solution is enough to prevent the deposition of a basic ferric acetate, it appears, unexpectedly, that in presence of ferric acetate in solution the titanium shows a very marked tendency to remain dissolved. Thus, an amount of iron alum the equivalent of 0.2 grm. of ferric oxide, together with 10 grm. of sodic acetate and seventeen per cent of absolute acetic acid, in a total volume of 400 $cm.^3$, held 0.06 grm. of titanic oxide completely in solution during boiling prolonged a quarter of an hour. In an experiment the counterpart of this, excepting only the addition of sodic acetate, the titanium began to deposit at once on boiling; and Streit and Franz,* in proposing the ebullition of the sulphates in presence of a large excess of acetic acid as a means of procuring titanic oxide free from iron, claim a complete precipitation under these conditions. The behavior of the sulphates of titanium and zirconium when in solution together appears to be analogous to this action of the acetates of iron and titanium, and iron in the ferric condition is generally supposed to influence somewhat the precipitation of titanium from the solution of the sulphates.

When iron and titanium appear together in solution, and are to be separated, the choice lies between Stromeyer's application of Chancel's hyposulphite method,† which yields milky filtrates, — always undesirable, — and that process which involves the precipitation of iron by ammonic sulphide in presence of ammonic tartrate to hold up the hydrates which would be precipitated in its absence. This latter method has been regarded as an undesirable one chiefly on account of the inconvenience involved in the evaporation of the filtrate from the ferrous sulphide and the ignition of the residue to remove the tartaric acid, and so to permit the recovery of bases. The difficulty in question may be obviated, however, by destroying the tartaric acid by potassic permanganate added gradually to the hot solution containing enough free sulphuric acid to leave some excess after the conversion of all the

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* Jour. prakt. Chem., cviii. 65.

† Ann. Ch. Pharm., cxiii. 127.

permanganate. The oxidation of tartaric acid by potassic permanganate does not, as is well known, yield carbonic acid and water alone, but gives rise also to a considerable quantity of formic acid as an intermediate product. When the permanganate begins to act upon the formic acid, the oxidation, going more slowly, results in the deposition of a brown manganic hydrate, which, if any tartaric acid remains in solution, redissolves quite rapidly, and, in presence of formic acid as the only reducing agent, more slowly. When, therefore, manganic hydrate is abundantly precipitated in the boiling solution, and does not perceptibly dissolve, it is quite certain that the conversion of the tartaric acid to formic acid — which is all that is needed in this case — has been accomplished; but for the sake of greater security the addition of permanganate may be continued until its color shows in the solution. It is well, however, to make use in this process of a known amount of tartaric acid, — experience has shown that an amount equal to three times the weight of the oxides to be held in solution is sufficient, unless ammonia be used in enormous excess and the boiling prolonged, — and to employ for its destruction two and a half times its own weight of potassic permanganate, this quantity being more than enough to carry the oxidation to the final products, providing there were no deposition of manganic hydrate. The manganese thus introduced into the solution may be removed by two acetate precipitations, which, if alumina is to be separated, must be made at any rate, even if no manganese be present.

To separate titanium, aluminum, and iron, therefore, I find it most convenient to precipitate the iron by passing hydric sulphide into the faintly ammoniacal solution of the oxides in ammonic tartrate, taking care that the solution is still ammoniacal just before filtering; to destroy the tartaric acid in the filtrate, after acidifying and boiling off the hydric sulphide by means of potassic permanganate in the manner just described, redissolving residual manganic hydrate by the addition of a little ammonic bisulphite and boiling off the excess of sulphurous acid; and to separate the titanium and aluminum by the acetate process.

A single point in the analysis of silicates may be worthy of note in this connection. If phosphoric acid be present, as is often the case, the separation of titanium from silica by the action of cold water upon the product of fusion in sodic or potassic bisulphate is liable to uncertainty, on account of the formation of the insoluble titanic phosphate which remains partly with the silica and in part clouds the filtrate. The siliceous residue should, therefore, be treated with sulphuric and

hydrofluoric acids to recover titanium which may be with the silica. It is better in most cases to effect the decomposition of a silicate by means of one of the fluoride methods, or by fusion in an alkaline carbonate, the melt in the latter case being acidified with hydrochloric acid, and the residue after evaporation and filtration worked over with sulphuric and hydrofluoric acids for the recovery of that portion of the titanium which remains insoluble after the evaporation.

XXI.

ATMOSPHERIC ELECTRICITY.

By Alexander McAdie and Austin L. McRae.

Communicated May 13, 1885.

By direction of the Chief Signal Officer, observations on atmospheric electricity were begun at Harvard College, Cambridge, Mass., under the supervision of Professor John Trowbridge, June 1, 1884.

By permission of the Chief Signal Officer the following abstract is taken from a report upon the apparatus used, and upon the observations from June 1, 1884, to April 30, 1885.

Electrometers.

A Thomson quadrant electrometer No. 26, and a Clifton modification of the Thomson, were originally used. A full description of the former can be found in the British Association Report for 1867, and also among the reprinted papers of Sir Wm. Thomson on "Electrostatics and Magnetism," Paper No. XX. The Clifton instrument is a modified form of the Thomson, designed for greater sensitiveness and of less complicated construction. It is not very generally known, and a brief description of it may therefore be given. The essential parts are four large brass or brass gilded quadrants, supported on glass rods of about 10 cm. length. A bifilar suspension carries an aluminium needle, corrugated and shaped like the figure eight. The length of the suspension is about 15 cm. A platinum wire from the needle dips into a glass vessel containing pure sulphuric acid, and coated on the outside and bottom with tinfoil. In the bottom of the case of the instrument, a circular opening is cut, of diameter sufficient to allow the removal of the glass vessel and the metal base on which it rests. In the upper part of the case is placed a small Thomson replenisher. The air within the case is kept dry by small open glass cups containing sulphuric acid. The needle is charged by means of a platinum wire imbedded in a gutta-percha rod, passing through the side of the case, and dipping into the sulphuric acid.

The instrument, as thus constructed, was found to be extremely sensitive, and admirably adapted to detect the smallest difference of potential of any two bodies, but for a long and continued series of observations, or single experiments of long duration, it was found unserviceable. The electric field of the quadrants was not sufficiently protected from external electrical influences. Two sides of the case only were coated on their interior surfaces with tinfoil, but the theory of the instrument demands, as far as possible, a complete shielding from external electrical influences. The great delicacy of the suspension is possibly the cause of the most serious defect, viz. a shifting of the zero point. The needle would never return exactly to its initial position. The difference was often great enough to give on a scale distant a meter from the mirror, a deflection of a centimeter. In the course of an hour a change in the position of the zero, when all the quadrants were connected, of from two to five or more millimeters would occur. These changes were in part due, no doubt, to a loss in the charge of the needle. To remedy the first defect, new suspending fibres were inserted without effect. To remedy the change due to dissipation of the charge, the vessel jar was paraffined around the edge, and for a time better results were obtained, though still faulty. The glass rods supporting the quadrants were several times taken out, washed with alcohol, dried, paraffined around the edges, and replaced. Other parts of the instrument, in which it was thought the fault might lie, were also carefully cleaned, and where needed provided with better insulation.

To obviate the difficulties met with in using the Clifton, the instrument described in the following sections was designed by Professor Trowbridge, and made at Boston, Mass. It is essentially the Clifton, so modified as to retain its great sensitiveness without having the defects mentioned. It was also desired to have an electrometer of more convenient arrangement than any of the forms now in use, — one in which the different parts should be amply protected from external influences, and yet be easily accessible for examination. The instrument devised has two compartments. In the upper compartment are the quadrants, needle, and suspending apparatus. In the lower compartment is the glass jar, with the arrangement for charging the needle. The upper compartment consists of a wooden case, 25 cm. high and 20 cm. square. On the top and back of the case are tight-fitting brass doors, the one at the top being 12 cm. square, the door at the back being 16 cm. high and 12 cm. wide. When open, these doors allow easy access to the suspending frame, and when shut, form

part of the metallic shield, covering and perfectly protecting the needle and quadrants from external electrical influences and also air currents. Circular brass windows 7 cm. in diameter, encased in brass and inserted in three sides of the case, allow inspection from without, of the needle, and also the passage of the beam of light to and from the mirror.

The bottom of the compartment consists of a brass plate of about 5 mm. thickness. From this plate rise, at alternate corners, two brass rods of 23 cm. height, supporting a cross-beam 20 cm. in length and 5 mm. in diameter. Fastened by a screw to this beam is a cross piece of 3.5 cm. length, supporting two suspending rollers. One roller has a screw movement to or from a central point exactly over the centre of suspension. The end of the roller is enlarged and grooved. One end of the suspending fibre is fastened to the roller by insertion through a small eye-hole in the shaft, and then made to pass in the enlarged groove. The other roller consists of a like brass shaft with an enlarged groove, in which the other end of the suspension fibre runs. This roller has not, however, a screw movement, and turning the screw head in this case simply raises or lowers the needle without change of position of the points of suspension. The whole suspension may be raised or lowered by movement of the screw-head attached to the supporting cross-beam. The plane of suspension may be altered by movement of the cross-bar, which is pivoted on the end of the screw passing through the cross-beam. This suspension is much simpler, equally sensitive with the best arrangements in other instruments, and in case of accident easily repaired. The length of the suspension is about 9 cm. Only one long fibre is employed. The platinum wire carrying the needle is hooked at its upper extremity, and by this means attached to the fibre. The weight of the needle is sufficient to insure a symmetrical suspension, without extra adjustment. If two separate fibres are used, and attached to a small cross-piece on the platinum wire, it will be necessary to test the symmetry of the suspension. The single fibre, however, allows a symmetrical suspension and with the arrangements employed allows easy and accurate adjustment. In the instrument constructed there is no error of position of the zero point. After the greatest deflection when short-circuited, the position of the spot of light on the ground-glass scale is exactly that of its initial position. Six months' constant use of the instrument has not necessitated the use of any correction for the position of the zero.

The needle is made of aluminium about 10 cm. in length, and at

its broadest parts about 2 cm. in width. The supporting platinum rod terminates in a small half-loop, just below the quadrants. To this loop a very fine platinum wire is attached, supporting a light lead paddle in the sulphuric acid of the glass jar. The quadrants are made of polished brass, the circle of which they are sections having a diameter of 15 cm. They are mounted on glass tubes, made of the best white glass, 5 cm. in height, and 1 cm. in diameter, and mounted on gutta-percha. Through the inside of the tubes run insulated wires imbedded in rubber, connected at the upper end with the quadrants, and at the lower end passing through the brass base plate to binding-screws in the walls of the lower compartment.

One of the quadrants can be slid out, the supporting rod being inserted in a brass plate moving in a groove cut in the base plate. A spring plate with a small projecting knob, fitting into the notches of the base plate, keeps this quadrant perpendicular and firm wherever it may be placed.

The lower compartment is 23 cm. high and 20 cm. square. In it is placed a glass jar of 15 cm. diameter and 10 cm. depth. The vessel is tinfoiled on the outside and bottom, and rests on a circular brass plate which can be either elevated or lowered several inches. The back of the compartment is hinged, and when opened allows full inspection. A platinum wire imbedded in gutta-percha passes through the side of the glass vessel about a centimeter from its upper edge. This wire dips into the acid of the jar.

The instrument, thus constructed, has been in constant use during the past six months, and, requiring but little attention, has proved itself very well adapted for work of this nature.

Multiple Quadrant Electrometer.

With a view to the construction of a portable electrometer sufficiently sensitive and accurate, the following instrument was designed by Professor Trowbridge and Mr. McAdie, and built according to their plans by the Western Electric Company of Boston. An exterior wooden case 30 cm. high and 12 cm. square, contains four compounded quadrants, a compound needle, and the suspending and charging arrangements. The outer case rests on a brass plate with the proper levelling arrangements, and is divided into three compartments, lettered A, B, and C. Each of these has one side at least hinged, so as to open and allow easy access to the interior. At the bottom of the front side of compartment A, a semicircular glass case 2 cm. in height projects. The bottom inside surface of this is mirrored in order to

eliminate errors of parallax in reading the position of a fine aluminium index playing over it. This uppermost compartment contains the suspension apparatus and the long light aluminium index arm. The suspension is as previously described. The aluminium pointer is carried by the platinum wire which supports the needle, but is insulated from it. A small concave mirror is also attached to the platinum wire, so that, if desired, the instrument can be employed with lamp and scale as a reflecting instrument. In the middle compartment B, four brass quadrants are mounted on flint-glass tubes of 4 cm. in length and 1 cm. in diameter. Each quadrant is compounded of four single quadrants. The dividing partitions fit into slots cut in the back plate, and are removable at pleasure. They are held in an exact horizontal position by means of small screws. The needle is made of aluminium, and is also of a compound type, being made of four or more single needles, connected and so arranged as to move between the quadrant sections. The interior surface of compartment B is completely tinfoiled. The third compartment contains a glass jar tinfoiled on the outer side and in connection with the ground. Through the side of the glass vessel is led a platinum wire encased in hard rubber. The deflection of the needle is recorded by the movement of the aluminium pointer. In the instrument constructed, when one set of quadrants is connected with the ground, the other to the positive pole of a Daniell cell, and the needle connected with the positive pole of a Beetz battery of 200 cells (described below), the movement of the index hand is perceptible to the unaided eye. On a scale distant 70 cm. from the mirror this deflection is nearly 2 cm. The length of the suspension is about 4 cm. Increasing the potential of the needle increases the sensibility of the instrument. If, instead of the method generally employed, we connect one set of quadrants with the positive pole of a battery of a number of cells connected in series, and the negative pole to the other set of quadrants and the needle connected with the body whose potential is to be determined, we obtain greater sensitiveness. The deflection obtained has then to be compared directly with the deflection given by a Daniell cell.

Connected in this manner, our electrometer gave a movement of the index hand, for a Daniell cell, of several degrees, or, with the mirror and scale, a deflection of about 4 cm.

For getting a continuous record, this form of electrometer is more easily adaptable than the others. It is also obvious that, aside from the difficulty and uncertainty of photography, an electrometer for successful use in meteorological work must be of such a nature

that its indications may be read at any time or place, and without delay.

Self-recording Apparatus.

We propose to place the following attachment on the multiple quadrant electrometer in order to render it self-recording. A metal plate is placed just above, and a metal cylinder with its axis horizontal just below, the metal index-pointer of the instrument. One terminal of the secondary circuit of a small Ruhmkorff coil is connected to the plate and the other to the cylinder. A strip of co-ordinate paper passing through a solution of iodide of potassium to keep it moist is drawn over the cylinder by clock-work. At regular intervals the primary circuit of the Ruhmkorff coil is broken for an instant by an automatic circuit-breaker, and a spark passes from the plate to the cylinder through the pointer, and registers on the paper the position of the pointer at the instant. Since the induced current will be of short duration, the spark will register the position of the index before the electrifications of the plate and cylinder can influence the needle. In this manner a record of every five minutes, or of every single minute, can be obtained without photography. The instrument need not be placed in a dark room, but may be moved around at will. The cost of the necessary apparatus for this registration will be more, but the expense of running it will be less, than the photographic apparatus. The great advantage of this apparatus will be that single observations can be made at any time without disturbing the record.

The preliminary experiments tried were successful; but as we have been unable to obtain a mechanician who could do the necessary mechanical work properly, the attachment has not been placed on the electrometer.

The Galvanometer.

A galvanometer was used to measure the potential of the atmosphere in the following manner. A condenser was charged by connecting one plate with the collector and the other plate with the ground. The condenser was then discharged through a ballistic galvanometer. By comparing the deflection of the needle with the deflection produced when the condenser is charged by a known electromotive force, and then discharged through the galvanometer, the difference of potential between the collector and the ground was obtained in absolute measure.

The Battery.

The needle of the electrometer was charged and kept at a constant potential by being connected to the positive pole of a constant battery, while the negative pole was connected to the ground.

At first, a zinc and copper distilled water battery of two hundred cells was used. The number of cells was afterwards increased to four hundred. The battery was placed in a large covered box to keep out the dust. The zinc used was common commercial zinc, and became coated with an oxide which had to be scraped off every two weeks. The evaporation of the water in a warm room was very great, so that the battery required constant care.

At the suggestion of Professor Trowbridge, we made a Beetz solid battery.* The cells consisted of glass tubes 10 cm. long and 1.2 cm. in diameter. One half of the tube was filled with white alabaster plaster of Paris mixed with a solution of copper sulphate. A copper wire was placed in this, and the plaster allowed to harden. Then the other half of the tube was filled with plaster of Paris mixed with a solution of zinc sulphate. A zinc wire was placed in this, and the plaster allowed to harden. The cells were connected in series. In order to save the time and trouble required to solder the copper of each cell to the zinc of the next, sheets of copper 10 cm. wide were soldered to similar sheets of zinc. These were then cut into strips, which were bent in the shape of a U. The copper end was placed in the plaster of Paris containing copper sulphate, and the zinc end in the plaster of Paris and zinc sulphate of the next cell. Care was taken that the wires should not extend quite to the middle of the cell, to prevent their coming in contact with the opposite sulphate. The ends of the cells and the connecting wires were dipped in paraffine to prevent the zinc and copper sulphates creeping along the wires. A battery of two hundred cells was made and placed in a box 60 cm. long, 40 cm. wide, and 20 cm. deep, which could be moved around easily. Care should be taken not to connect the terminals, for the battery will polarize and soon destroy itself. Six cells were experimented upon in November, 1884, to determine their electromotive force and internal resistance. They worked perfectly until the latter part of February, 1885, when they gave out. Their average electromotive force was 1.06 volts; their average internal resistance, 1,600 ohms. The rest of the battery does not seem to

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* Phil. Mag., March, 1884.

have deteriorated any, although it has been in constant use since November 15, 1884.

An extra cell was made whose electromotive force was 1.04 volts. It has been tested occasionally since, and found to remain constant.

A distilled water cell was completely covered with paraffine. Although it has remained nearly constant, some of the water has been lost, and the zinc is now coated with a thick deposit.

At the same time these cells were made, we made another in the following manner. A copper cylinder six centimeters long and one centimeter in diameter was filled with plaster of Paris mixed with a solution of zinc chloride containing a small per cent of sodium chloride. A zinc wire was placed in this, and the plaster allowed to dry. This cell has an electromotive force of .80 volt, and an internal resistance much less than a Beetz cell. It has remained constant up to date.

A Beetz battery can be made of compact size, and imbedded in paraffine or some solid insulating substance, and made portable so as to be used in connection with a portable electrometer.

This is decidedly the best kind of a battery to use in electrostatic measurements. It has the advantage over the water battery of being cheaper, of being smaller and more convenient to move, and it requires little attention after it is made.

The Collector.

The water-dropping collector proposed and used by Sir William Thomson* was employed at first. It consists of an insulated metallic vessel filled with water and connected to the electrometer. Water drops from the nozzle of the vessel, and reduces it to the potential of the air at the point where the stream ceases to be continuous.

A more convenient arrangement of the same principle is to allow the water to drop first on an insulated metallic plate connected with the electrometer, and then to the ground. The vessel containing the water need not be metallic nor insulated. Water dropping from the plate reduces it to the potential of the air, in the same manner that the nozzle of the vessel was reduced. The metal plate used was of brass 10 cm. by 15 cm. It was placed from five to ten centimeters below the nozzle. Different-sized plates of copper and of brass were used without appreciably affecting the results. With zinc and other plates there was a slight contact electricity between the plate and the brass quadrants of the electrometer. The plate has the double

* Papers on Elect. and Mag., § 262.

advantage over the metallic vessel of being more convenient to arrange and more easily insulated when the humidity of the air is high. The electricity produced by the impact of the water upon the plate is too slight to be measured.

Mechanical Collector.

Continuous records cannot be obtained in this climate with the water-dropper, because in winter water will freeze before it has been dropping long. At the suggestion of Professor Trowbridge several mechanical collectors were tested to see if any could be found that would be superior to the water-dropper.

1. The first consisted of a wheel thirty centimeters in diameter, with strips of tinfoil fastened to its circumference in such a manner that when the wheel revolved on a horizontal axis the pieces of tinfoil touched successively two metal knobs, A and B. A was connected to the electrometer, and B to the ground. When the wheel revolved, each strip of tinfoil carried off a part of the charge of A, and discharged it to the ground through B. Now A, losing continuously a part of its original charge, would approximate nearer and nearer to the potential of the surrounding air.

2. The second consisted of a pendulum attached to a framework. A non-conducting fibre with a metal ball at its lower end passed up through a hole in the framework and was attached to the bob of the pendulum. A piece of metal, G, connected to the ground, was placed in such a position that, when the pendulum hung vertically, the ball rested lightly on G. Another piece of metal, E, connected to the electrometer, was so placed that, when the pendulum swung to either side, the ball touched E. When the pendulum was in motion, the action was the same as in the first experiment. The proper facilities were not at hand for carrying out these experiments to the best advantage, so that the results were not satisfactory. With the apparatus used, the electricity produced by friction was too great to be neglected.

3. Fine platinum wires were attached at equal intervals to the dial-plate of a minute clock, in such a manner that the seconds hand could strike them. The clockwork was of sufficient strength not to be stopped when the hand came against a wire. Each alternate wire was connected to the ground. The others were connected to a metallic plate in the air, and to the electrometer. The seconds hand was insulated from each set. The principle is the same as in the first and second examples.

4. We next made use of the principle, that, if a metallic sphere is carried out in the air and connected by a fine wire to the ground, and then insulated, it will have the potential of the air.* Two wires connected together were placed on the dial of the clock described above, and carefully insulated from the clockwork. They were connected to a metal plate in the air, and to the electrometer. The hands of the clock were connected to the ground. The clock was placed inside of a box lined with tinfoil and hung upon the wall of the room. The tinfoil was connected to the ground. In this way the clock was shielded from the influence of the electricity of the room, and also from the effects of the weather without. A rubber hose ending in a glass tube was placed near the plate, and air drawn in over the plate through the hose by an aspirator. By this means the air around the plate was continually renewed. When the clock was running, the plate was connected to the ground every half-minute for a moment, and then insulated, and therefore took the potential of the adjacent air. When the plate was connected to the ground, the needle would tend to swing toward the zero, but the plate being immediately insulated, the needle would return to the proper deflection. The needle used had sufficient inertia to prevent much swinging. There was only a slight oscillation. In using this collector, if the inertia of the needle is small, the clock can be stopped long enough to take an observation after it has once been in operation and connected the plate to the ground.

With all these collectors, including the water-dropper, we do not measure the difference of potential between the ground and the air, but between the ground and some combination of the ground and air. If the ground is zero, the results will be correct; but if the ground has a local charge, the results will be a combination. For instance, when the mechanical collector is grounded, it takes the potential of the ground. Being then insulated, it combines this potential with the potential of the air, and the electrometer measures the difference between the ground and this combination. In the case of the water-dropper, water is drawn from the pipes in contact with the ground, so that the electrometer measures the difference between the potential of the ground and the combination formed by the charge of the water and the charge of the air. It is probable that this effect is generally very small, and is soon neutralized; but under certain circumstances, (e. g. when an electrified cloud is near the place of observation,) it

* Maxwell's Elect. and Mag., sect. 221.

may be of sufficient magnitude to destroy the value of the observation. In a continuous record, we could not compare the results when this effect was acting with those when it was not acting, and deduce any valuable laws. It was thought that by connecting the positive pole of the battery to one set of quadrants, and the negative pole to the other set, and then connected first to the ground and then to the collector, (the deflection of the needle being noted in each case,) the effect of a local charge in the ground could be eliminated. This was tried with very good results, but it would not be accurate if rapid changes were taking place at the time of observation, nor could it be used to obtain a continuous record.

In order, therefore, to overcome the various difficulties of the collectors described, we made use of the following principle.

Maxwell * says: "Now let us suppose a firm insulated wire carried from the electrode of the electrometer to the place where the potential is to be measured. Let the sphere be first completely discharged. This may be done by putting it into the inside of a vessel of the same metal which nearly surrounds it, and making it touch the vessel. Now let the sphere thus discharged be carried to the end of the wire and made to touch it. Since the sphere is not electrified, it will be at the potential of the air at the place. If the electrode wire is at the same potential, it will not be affected by the contact; but if the electrode is at a different potential, it will by contact with the sphere be made nearer to that of the air than it was before. By a succession of such operations, the sphere being alternately discharged and made to touch the electrode, the potential of the electrode will continually approach that of the air at the given point."

We applied this principle to experiment 2 by making G a metal cup, but the height the ball was raised was so small that we abandoned that method, and constructed the following collector, which seems to be free from all the greater objections. It consists of a framework supporting a brass cup. A non-conducting string with a brass sphere at one end passes through a system of pulleys. A brass plate is attached to the framework just above the cup. It is insulated from the framework by a thick layer of paraffine. The cup is connected to the ground, and the plate to the electrometer. By means of the string the sphere can be made to touch the inside of the cup and the plate successively, and thus reduce the plate to the potential of the air.

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* Elect. and Mag., sect. 221.

The sphere can be raised and lowered by means of clockwork, an electric motor, or a water motor. The laboratory has a small water motor, which was used for this purpose by attaching an arm to the circumference of the wheel and fastening the end of the string to this arm. When the arm is in a certain position of its revolution, the sphere rests lightly on the bottom of the cup. When the arm has turned 180° from this position the sphere touches the plate.

The sphere, cup, and plate must be of the same metal. As the quadrants of the electrometer are of brass, we made these of brass to avoid all contact electricity.

Comparative observations have been made with this collector and the water-dropper for a month. The changes seem to be similar, but the deflections of the water-dropper are the larger.

It seems possible, with some mechanical improvements, to make this form of collector superior to any other.

Observations.

The observations show that —

The potential of the air was generally low and positive, seldom as high as 25 or 30 volts.

The potential usually fell before precipitation, storms, or when the relative humidity increased.

The potential during precipitation, with a very few exceptions, was always low and positive.

Almost all the negative electricity, except that which was followed by precipitation, occurred during west to northwest gales, or during cold waves.

Low clouds sometimes seemed to affect the observations, but high clouds seemed to have no influence.

There was very slight variation with altitude, — at least, between two and ten meters above the ground.

There was no appreciable variation between collectors placed on different sides of the building.

On Obtaining the Electric Potential of the Upper Air.

On the morning of May 6th, the potential of the air at a point ten feet above the ground and three feet from the walls of the laboratory, obtained by the usual water-dropping method, was, reduced to volts, 0.5. A paper kite covered with cloth and tinfoil, with its longest axis about four feet, was flown, the connecting string being heavy English

twine, previously soaked in a mixture of glycerine and water. The end of this string was connected to a wire well insulated, which in turn was connected to one set of the quadrants of the Trowbridge electrometer, the other set of quadrants being connected with the ground. The needle was connected to the positive pole of a Beetz solid battery of 200 cells (200 volts). The needle was at once deflected to its limit, indicating a high positive potential for the air at an elevation of less than 300 feet. Remaining for a few seconds at this high positive, it would suddenly change to an equally high negative, sometimes without the least warning. It was, without doubt, extremely variable. The high positive indications seemed to be more prevalent. Connecting the kite-string with the multiple quadrant electrometer, described in this paper, the following results were obtained. The connection and charge of the needle were as in the other instrument. A fine index-pointer records the deflections in this instrument, and the mirror, scale, and dark room are dispensed with. A Daniell cell gives a deflection of half a degree. The deflection given by the kite was at times over 25 degrees in a positive direction, or equivalent to over 100 volts. The index-hand was seldom still, as in the previous case evidencing an extreme variableness of the electrical condition of the air at that place and time. The wind was from the east, steady and light, the pressure 30.061, the temperature 49° F., the relative humidity 77, and the sky covered with a low pallium of stratus clouds moving from the east slowly.

On the next day, May 7, the kite was again flown, this time reaching an altitude of about 500 feet. The potential of the air at a point ten feet from the ground, obtained by a water-dropper, reduced to volts, was 0.4.

The table on the following page shows the deflections for short intervals. These deflections were comparatively steady, and had not the variableness of those on the preceding day. The wind was east, and had now been blowing from that quarter for nearly thirty hours. The sky was covered with stratus clouds, having the unusual appearance of billows with the crests pointing to the earth. The pressure was 30.040, the temperature 45° F., the relative humidity 75.

The experiment demonstrates that it is comparatively easy to obtain some indication, even if it be only a relative one, of the potential of the air at high altitudes. The method is simple and direct, and with the exception of the original cost of electrometer and charging battery, quite inexpensive. A series of simultaneous observations of this character would doubtless be of value in meteorology.

TABLE OF DEFLECTIONS.

Time. May 7.	Deflection.	Deflection reduced to Volts.	Wind	Remarks.
h. m. s.				
12 0 0 M.	12.0	24.0	E.N.E.	
12 5 0 P. M	+12.5	25.0	E.N.E.	
12 5 30 "	+11.5	23.0	E.N.E.	
12 5 45 "	+12.0	24.0	E.	
12 6 0 "	+10.7	21.5	E.	
12 6 15 "	{ + 9.5 / +11.5 }	{ 19.0 / 23.0 }	E.	Kite diving.
12 6 30 "	+11.5	23.0	E.	
12 6 45 "	+ 9.5	19.0	E.	
12 7 0 "	+ 9.5	19.0	E.	
12 7 15 "	+ 9.75	19.5	E.	
12 7 30 "	+10.0	20.0	E.	Gust of wind.
12 7 45 "	+ 9.5	19.0	E.	
12 8 0 "	+10.0	20.0	E.	
12 8 15 "	+10.5	21.0	E.	
12 8 30 "	+10.5	21.0	E.	
12 8 45 "	+10.5	21.0	E.	
12 9 0 "	+11.0	22.0	E.	
12 9 15 "	+11.5	23.0	E.	
12 9 30 "	+12.0	24.0	E.	
12 9 45 "	+11.75	23.5	E.	
12 10 0 "	+12.0	24.0	E.	
12 25 0 "	11.25	22.5	E.	
12 26 0 "	10.0	20.0	E.	
12 26 5 "	10.0	20.0	E.	
12 26 10 "	10.0	20.0	E.	
12 26 15 "	11.5	23.0	E.	
12 26 20 "	10.75	21.5	E.	
12 26 25 "	11.0	22.0	E.	
12 26 30 "	11.5	23.0	E.	
12 26 35 "	11.0	22.0	E.	
12 26 40 "	11.25	22.5	E.	
12 26 45 "	11.25	22.5	E.	
12 26 50 "	11.0	22.0	E.	
12 26 55 "	11.25	22.5	E.	
12 27 0 "	11.75	23.5	E.	

JEFFERSON PHYSICAL LABORATORY.

INVESTIGATIONS ON LIGHT AND HEAT, MADE AND PUBLISHED WHOLLY R IN PART WITH APPROPRIATION FROM THE RUMFORD FUND.

XXII.

THE EFFECT OF TEMPERATURE ON THE MAGNETIC PERMEABILITY OF IRON AND COBALT.

BY JOHN TROWBRIDGE AND AUSTIN L. MCRAE.

Communicated May 13, 1885.

THESE experiments were made with a view, —

1. To repeat Professor Rowland's experiments.*
2. To determine the change of the magnetic permeability with
   a. The change of temperature.
   b. The variation of the size and thickness of the rings.
   c. The temper of the substance.
3. To determine whether the outer layer of the substance shielded the inner layers from magnetic influence.

The method of experiment was the same as Rowland's, except that the small coil around the horseshoe magnet used to bring the needle to rest was taken out of the circuit of the induced current, and a thermal junction of copper and german silver was placed in the lamp used with the mirror galvanometer, and the circuit made through the galvanometer and a key. This circuit was independent of the induced current circuit. By closing the key, a thermal current could be sent through the galvanometer. This arrangement served the same purpose as the sliding coil on the magnet, and was more convenient.

The measurements are made in the C. G. S. system of absolute units.

The symbols used are:

H = intensity of the magnetizing force.
B = magnetic induction, or the number of lines of force passing through a unit of area.
M = magnetic permeability.

* Phil. Mag., 1873, 1874.

$T =$ temporary part of B.
$N_0 =$ total number of coils on the ring magnet.
$a =$ mean radius of the ring.
$r =$ radius of cross-section of the ring.
$\gamma =$ strength of the current.
$N =$ number of coils on the helix.
$N' =$ number of coils on the earth inductor.
$R =$ radius of earth inductor.
$C =$ deflection of earth inductor.
$h =$ deflection of the helix when the current is reversed.
$h' =$ deflection of the helix when the current is broken.
$V =$ vertical force of the earth's magnetism.
$\delta =$ deflection of the tangent galvanometer.

The magnetic potential inside of a ring solenoid is

$$\Omega = -2 N_0 \gamma \theta,^*$$

where θ is the azimuth angle about the axis of the ring.

Differentiating, we have

$$\frac{d\Omega}{ds} = -2 N_0 \gamma \frac{d\theta}{ds};$$

but $\frac{ds}{d\theta} = \rho$, the distance from the axis; hence the magnetic force

$$= -\frac{d\Omega}{ds} = \frac{2 N_0 \gamma}{\rho}.$$

To find the total number of lines of force passing through any area, we find an expression for the force at a single point, and then integrate this expression all over the surface between the proper limits.

If we take a section of the ring and divide it into bars of length BC and width dx, we shall have $BC = 2\sqrt{r^2 - x^2}$, and we shall find the total number of lines of force through the section to be equal.

$$\int_{-r}^{+r} \frac{2 N_0 \gamma M}{a - x} 2\sqrt{r^2 - x^2}\, dx = 4\pi N_0 \gamma M (a - \sqrt{a^2 - r^2})$$

$$= \frac{2 N_0 \gamma}{a} M \pi r^2 \left(1 + \frac{1}{4}\frac{r^2}{a^2} + \frac{1}{8}\frac{r^4}{a^4} + \text{\&c.}\right) = \frac{2 N_0 \gamma}{a} M \pi r^2,$$

since in the rings used the parenthesis differs but little from unity.

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* Maxwell's Elect and Mag., sect. 681.

The magnetic induction = total number of lines of force divided by the area of the section; therefore

$$B = \frac{2\,N_0\,\gamma}{a}\,M = H_r M.$$

In order to obtain the magnetic induction in absolute measure, the deflections of the helix were compared with the deflection of an earth inductor in the same circuit, thus: —

$$h : C :: 2\,N \pi r^2 B : 2\,N' \pi R^2 V,$$

or

$$B = \frac{N' \pi R^2 V h}{\pi r^2 N C}.$$

Similarly,

$$T = \frac{2\,N' \pi R^2 V h'}{\pi r^2 N C}.$$

We have seen that

$$H = \frac{2\,N_0\,\gamma}{a} = \frac{2\,N_0\,\kappa \text{ tang. } \delta}{a}.$$

The reduction factors of the tangent galvanometer used in Tables I. and II. are:

$$K_1 = .0582.$$
$$K_2 = .0625.$$
$$K_3 = .2902.$$

The reduction factors of the tangent galvanometer used in the other tables are:

$$K_1 = .008868.$$
$$K_2 = .01972.$$
$$K_3 = .0876.$$
$$K_4 = .4435.$$

Both the tangent and the mirror galvanometer were placed upon the stone piers of the laboratory.

C is the mean of from six to ten readings; h and h' are the mean of four; and δ is the mean of four readings, two before and two after h and h' were taken.

The vertical component of the earth's magnetism at Cambridge, Mass., is 0.5406.

DIMENSIONS OF THE RINGS.

W = weight of ring in air. W_1 = weight in water. S = specific gravity.

Table.	Ring.	r.	a.	W.	W_1.	S.	No.	$N' \pi R^2$.
I.	1	.700	5.46	....	....	7.83	323	42080
II.	2	.700	5.415	....	....	7.83	343	42080
III.	3	.468	5.007	165.98	144.35	7.67	750	42080
IV.	4	.4215	4.33	119.2	104.03	7.85	332	42080
V.	4	.4215	4.33	....	....	....	313	40427
VI.	4	.4215	4.33	....	....	....	296	40427
VII.	5	.698	3.164	236.0	205.54	7.75	200	3503
VIII.	5	.698	3.164	....	....	....	200	40427
IX.	6	$r_1 = .360$ .698	3.20	175.2	....	7.75	200	3503
X.	6	.698	3.20	....	....	....	200	40427
XI.	Cobalt	.637	4.495	286.77	250.80	7.966	500	42080
XII.	Cobalt	.637	4.495	....	....	....	544	3421

TABLE I.

Iron normal. 10° C.

δ.	C.	h.	N.	H.	B.	M.
K_2 3.4	13.8	10.9	30	.424	445	1020
4.6	14.0	7.46	10	.745	901	1524
6.9	....	18.41	10	.902	2225	2465
9.1	14.1	9.53	3	1.18	3812	3221
20.9	....	8.14	1	2.83	9768	3455
35.4	....	11.01	1	5.26	13209	2512
55.85	....	13.21	1	10.9	15846	1451
69.1	14.1	14.24	1	19.0	17156	882
K_3 40.65	....	14.75	1	29.4	17700	597
51.9	14.2	15.25	1	43.8	18590	415

TABLE II.

Iron normal. —18° C.

δ.	C.	h.	N.	H.	B.	M.
K_1 2.55	13.93	3.01	20	.317	183	576
3.0	....	4.05	....	.384	246	642
K_2 3.15	13.95	6.22	....	.436	377	846
4.2	....	11.7	....	.578	710	1200
5.0	....	18.66	....	.689	1131	1604
6.15	14.1	16.36	10	.855	1963	2296
7.1	....	6.64	3	.990	2656	2684
8.3	....	8.88	....	1.156	3552	3073
9.8	....	11.73	....	1.362	4691	3445
12.05	14.0	15.37	....	1.695	6191	3655
14.15	....	18.21	....	1.988	7335	3692
16.85	....	7.07	1	2.40	8542	3562
20.75	....	8.24	....	3.00	9955	3320
33.5	....	10.75	....	5.244	12990	2480
42.9	....	11.92	....	7.365	14403	1957
K_3 27.6	13.85	13.99	....	19.96	17092	837
51.1	....	15.11	....	49.23	18456	375

TABLE III. — Dec. 27, 1884.

Iron normal. —7° C.

δ.	C.	h.	h′.	N.	H.	B.	T.	M.
K_1 5.1	9.4	1.1	0.5	45	.2365	86	78	364
6.1	....	1.4	0.7	....	.2843	109	109	385
8.4	....	2.3	1.0	....	.3933	180	156	457
12.1	....	4.0	1.6	....	.5582	313	250	548
15.0	....	6.5	2 3	....	.7120	508	360	714
18.5	....	10.8	3.1	....	.8875	844	484	952
22.8	....	22.0	4.5	....	1.116	1720	704	1541
27.6	9.3	8.5	1.2	10	1.390	3022	854	2174
30.5	....	10.5	1.4	....	1.565	3732	996	2385
37.6	9.3	16.1	1.7	....	2.045	5724	1208	2798
K_2 32.1	....	9.0	0.9	3	3.7085	10664	2132	2876
35.4	....	9.7	1 0	....	4.203	11500	2370	2735
38.0	....	10.3	1.2	....	4.617	12200	2844	2645
41.4	....	11.0	1.3	....	5.210	13050	3080	2503
45.0	....	11.6	1.45	....	5.910	13750	3440	2327
48.9	....	12.3	1.6	....	6.770	14570	3790	2153
53.0	....	12.95	1.8	....	7.841	15350	4264	1958
K_3 19.6	9.2	13.75	1.95	....	9.502	16574	4672	1734
24.5	....	14.5	2.2	....	12.206	17380	5272	1423
31.4	....	15.25	2.6	....	16.03	18260	6230	1140
43.7	....	16.3	3.0	....	25.08	19533	7188	779
53.5	....	16.8	3.3	....	35.475	20130	7906	567
K_4 20.0	....	17.3	3.7	....	48.377	20723	8866	428
25.0	9.2	17.6	4.1	....	61.930	21018	9824	340

TABLE IV. — Dec. 26, 1884.

Iron magnetic. 15° C. Heated to red heat and allowed to cool slowly.

δ.	C.	h.	h'	N.	H.	B.	T.	M.
K_1 8.1	9.5	0.6	....	30	.1945	86	....	441
9.5	9.5	1.4	....	45	.227	133	....	587
11.2	....	1.7	....	....	.269	162	....	601
24.6	....	7.7	2.4	....	.623	734	458	1150
34.1	....	21.3	3.1	30	.919	3474	886	3779
52.1	....	19.2	1.6	10	1.793	8234	1372	4592
57.1	....	21.2	2.1	....	2.100	9090	1800	4330
K_2 57.5	9.5	8.6	0.7	3	4.75	12300	2000	2590
70.6	....	10.0	1.5	....	8.596	14300	4290	1663
K_4 9.4	....	10.3	2.1	....	11.13	14720	6000	1331
18.8	....	10.6	....	....	23.13	15000	....	649
26.8	....	11.0	....	....	34.43	15720	....	457
32.1	....	11.2	2.4	....	42.7	16000	6860	375

TABLE V. — April 18, 1885.

Iron magnetic. 18° C. Hardened.

δ.	C.	h.	N.	H.	B.	M.
K_1 4.6	5.5	0.25	45	.100	40	385
13.65	....	1.35	....	.311	214	686
20.4	....	2.7	....	.477	427	896
32.55	....	9.2	....	.818	1455	1780
43.95	....	17.6	....	1.236	2785	2254
K_3 10.5	....	10.4	16	2.34	4680	1975
16.45	....	14.0	....	3.74	6230	1665
26.3	5.5	18.5	....	6.26	8230	1315
33.7	....	20.95	....	8.45	9320	1105
42.5	....	24.5	....	11.6	10900	940
55.0	....	8.2	5	18.1	12100	669

TABLE VI. — April 20, 1885.

Iron magnetic. 20° C. Softened.

δ.	C.	h.	N.	H.	B.	M.
K_1 15.25	5.4	3.2	45	.331	516	1560
26.55	....	13.25	....	.606	2185	3520
36.55	....	7.2	10	.902	5220	5790
49.15	....	12.1	....	1.40	8770	6260
K_3 16.6	....	17.5	....	3.57	12700	3550
24.55	....	18.8	....	5.47	13640	2490
41.75	5.4	5.8	3	10.7	14000	1310
57.55	....	6.1	....	18.8	14750	783

TABLE VII. — April 13, 1885

Iron normal. 18° C.

δ.	C.	h.	h′.	N.	H.	B.	T.	M.
K_1 5.7	12.9	11.8	5.1	25	.112	45	39	404
8.5	....	20.1	8.3	....	.168	77	64	460
10.6	....	27.0	....	....	.210	104	....	494
13.4	....	14.1	5.95	10	.267	135	114	509
18.4	....	22.6	9.3	....	.373	217	178	581
22.0	....	8.4	3.5	3	.453	269	224	593
26.5	....	11.7	4.75	....	.559	374	304	669
33.5	....	18.2	7.1	....	.742	582	454	784
38.5	....	25.5	8.6	....	.892	815	550	914
K_3 7.25	....	16.2	4.5	1	1.41	1554	863	1100
9.9	....	35.5	6.0	....	1.93	3405	1150	1760
13.4	4.8	24.8	3.1	1	2.64	6394	1600	2426
18.1	....	34.0	4.0	....	3.62	8766	2060	2420
30.75	1.5	13.8	1.7	....	6.59	11400	2475	1730
40.25	....	15.6	2.2	....	9.38	12850	3200	1370
45.4	....	16.3	....	....	11.2	13450	....	1195
52.4	....	17.1	....	....	14.4	14100	....	980
59.8	....	17.9	2.9	....	19.03	14800	4210	776

TABLE VIII. — April 17, 1885.

Iron magnetic. 18° C.

δ	C.	h.	h′.	N.	H.	B.	T.	M.
K_1 5.7	5.5	0.25	....	30	.112	22	....	193
10.9	....	0.55	....	....	.215	48	....	221
20.25	....	1.4	....	....	.414	121	....	293
30.05	....	2.5	....	....	.648	216	....	334
41.0	....	5.26	....	....	.974	455	....	467
K_3 8.4	....	20.3	....	....	1.64	1755	....	1073
11.1	....	14.6	....	10	2.17	3790	....	1750
15.0	....	24.1	....	....	2.97	6260	....	2100
22.55	....	10.45	....	3	4.60	9040	....	1970
34.35	....	13.05	....	....	7.57	11300	....	1490
49.9	....	15.1	....	....	13.17	13100	....	993
58.6	....	16.15	....	....	18.14	14000	....	770
K_4 19.0	5.5	5.4	.875	1	19.3	14000	4540	727
29.5	....	5.625	.975	1	31.7	14600	5060	460
35.5	....	5.85	1.1	....	40.0	15200	5710	379
40.6	....	5.925	1.1	....	48.1	15400	5710	320

TABLE IX. — April 13, 1885.

Hollow iron ring, normal. 18° C.

δ.	C.	h.	h′.	N.	H.	B.	T.	M.
K_1 5.2	12.9	4.7	2.0	25	.101	25	21	242
8.2	....	8.85	3.6	....	.162	46	38	286
10.85	....	13.6	5.3	....	.215	71	55	331
16.1	....	9.7	3.5	10	.324	127	98	391
18.6	....	12.0	4.7	....	.377	157	120	416
24.1	....	5.8	2.1	3	.501	253	183	504
26.5	....	6.9	2.7	....	.559	301	235	537
33.7	....	13.3	3.9	....	.748	579	340	775
38.65	....	21.3	5.4	....	.897	928	470	1035
K_3 7.4	....	15.5	2.7	1	1.44	2025	706	1405
10.3	....	28.8	....	....	2.01	3764	....	1870
13.9	4.8	16.8	2.2	....	2.74	5900	1540	2206
18.1	....	21.3	2.8	....	3.62	7480	1970	2070
31.0	1.5	9.0	1.5	....	6.65	10100	2980	1520
40.1	....	10.05	1.8	....	9.32	11300	3570	1210
45.25	....	10.7	....	....	11.2	12000	....	1076
52.55	....	11.3	2.2	....	14.5	12700	4360	878
58.8	....	12.1	....	....	18.3	13600	....	744

TABLE X. — April 17, 1885.

Hollow iron ring, magnetic. 18° C.

δ.	C.	h.	h′.	N.	H.	B.	T.	M.
K_1 11.0	5.5	0.3	....	30	.215	35	....	164
40.9	....	9.2	....	....	.960	1085	....	1130
K_3 8.55	....	17.5	....	....	1.65	2060	....	1250
11.1	....	10.6	....	10	2.15	3750	....	1750
14.9	....	15.4	....	....	2.915	5450	....	1870
22.3	....	6.35	....	3	4.49	7490	....	1670
33.25	....	8.2	....	....	7.18	9890	....	1350
49.4	....	10.1	....	....	12.9	11900	....	924
58.1	....	10.8	....	....	17.6	12700	....	724
K_4 16.55	5.5	10.25	2.2	....	16.5	12100	5180	733
25.5	....	11.6	2.75	....	26.45	13700	6480	517
33.15	....	12.3	2.85	....	36.2	14500	6720	400
41.85	....	12.8	3.2	....	49.6	15100	7540	304

TABLE XI. — Dec. 27, 1884.

Cobalt magnetic. —5° C. Softened.

δ.	C.	h.	h′.	N.	H.	B.	T.	M.
K_1 8.5	9.2	0.7	0.3	50	.298	27	23	91
11.7	....	1.1	0.5	....	.410	43	39	104
22.6	....	2.3	1.1	....	.823	89	85	109
30.7	....	3.7	1.6	....	1.175	144	124	122
39.4	....	5.55	2.4	....	1.625	215	186	133
46.5	....	7.8	3.3	....	2.084	303	256	145
51.5	....	9.8	4.15	....	2.49	380	322	153
K_2 51.9	....	25.1	9.3	....	5.61	974	722	174
K_3 18.5	9.2	7.1	2.5	10	6.53	1377	970	211
24.6	....	11.4	3.5	....	7.10	2211	1358	311
31.9	....	18.4	5.5	....	12.17	3570	1978	293
41.4	....	25.4	6.95	....	17.22	4927	2678	286
50.5	....	9.5	2.65	3	23.65	6143	3426	260
K_4 20.2	....	11.5	3.35	....	36.4	7437	4332	204
28.6	....	13.6	4.2	....	53.9	8794	5432	163
40.55	....	15.35	4.9	....	84.6	9928	6338	117

TABLE XII. — April 30, 1884.

Cobalt magnetic. 20° C. Hardened.

δ.	C.	h.	h′.	N.	H.	B.	T.	M.
K_3 6.55	13.3	15.3	7.2	45	3.10	37	35	12
11.8	....	7.82	3.6	10	5.48	85	79	16
21.5	....	17.2	7.6	....	10.5	188	166	18
31.25	13.3	2.73	1.25	1	16.2	298	273	19
41.63	....	4.7	1.9	....	23.7	513	415	22
K_4 32.0	....	22.7	6.85	....	84.5	2476	1495	29
39.1	....	23.6	6.88	....	110.	2575	1500	23

All the iron rings were forged. The cobalt ring was cast.

Four of the iron rings were made from the same bar of Norway iron, and were of nearly the same size. Nos. 1 and 2 are two of them. The third was cooled down to —25° C. or —40° C. by means of liquefied nitrous oxide, and a partial curve taken. The fourth was heated up to 280° C. in liquid paraffine, and a few measurements taken. Although complete curves were not obtained at either of these temperatures, the part obtained differed but slightly from the corresponding parts of the curves of Nos. 1 and 2.

In order to prevent the insulation from being destroyed at the high temperature, the ring was completely covered, except in three places,

with thin asbestos paper, and each turn of the coil was separated from the next by an asbestos string wound around the ring. Only one layer of wire was used. The small uncovered portions of the ring allowed it to take the temperature of the paraffine without materially affecting the uniformity of the winding.

From the curves of the other rings there does not seem to be any definite difference between the values of M due to the variation of the diameter or of the cross-section of the rings.

The temper of the metal seems to exercise a much greater influence upon the magnetic permeability than any other physical condition. This is shown by an inspection of Tables IV., V., and VI. for iron, and XI. and XII. for cobalt.

The iron ring 4 was heated to red heat and allowed to cool slowly, and it gave Table IV. It was then heated and plunged into cold water, and then gave Table V. We wished to see if it would regain its permeability on being softened again. It gave Table VI., in which the maximum value of M is greater than after the first annealing.

The maximum value of M for soft iron is about three times its maximum value for the same iron hardened.

The maximum value of M for soft cobalt is ten times as great as the maximum value for the same cobalt hardened.

Shielding of Magnetic Influence.

We next wished to determine whether or not the outer layers of the ring shielded the inner layers from magnetic influence.

Professor Bosanquet * endeavored to decide this question by comparing the magnetic induction, for equal magnetizing forces, in rings of different cross-section. He said there was no shielding. It is evident from the preceding tables, that the quality of his metal would make such a large difference in the values of the induction as to completely mask the shielding effect if there were any.

We think the method tried by us more suitable to determine the question. A solid and a hollow ring were made from the same bar of iron, and of nearly the same diameter.

The hollow ring was made by cutting off a bar of the proper length, and drilling a hole along its axis. Then the tube thus formed was bent around and forged without closing the hollow. The radius cross-section was 0.698 cm., and the radius of the hollow, calculated from the equation $\pi r^2 - \pi r^2 =$ weight divided by the density,

* Phil. Mag., February, 1885.

was 0.360 cm. This is what was used in the tables. After completing the experiments upon the hollow ring, it was sawed open, in order to see that it was hollow, and to measure the thickness of the shell. The diameter of the hollow was almost, but not exactly uniform, and the average of the measured values of its radius was a little larger than 0.360 cm. It seemed that the hollow had been made a little larger than the drill at and near the place where the ring had been forged. This would make B, T, and M a trifle larger in Tables IX. and X., and would make the magnetic induction and the permeability more nearly equal to those of the solid ring in Tables VII. and VIII., while it would make the difference in the temporary magnetism of the two rings greater.

The mirror galvanometer used in Tables VII. and IX. was so sensitive that resistances had to be placed in the induced current circuit. This made the deflection of the earth inductor very small, and may probably have introduced an error. But as these tables were made especially to get the difference between the solid and the hollow ring, and as they were tried under exactly similar circumstances, the same errors would appear in both tables.

As far as this single experiment goes, it shows that the temporary magnetism is greater in the hollow than in the solid ring, consequently the permanent magnetism has a larger value in the solid ring. It also shows that the axis of the curve of the hollow ring is more inclined to the axis of M than that of the solid ring is.

Jefferson Physical Laboratory.

INVESTIGATIONS ON LIGHT AND HEAT, MADE AND PUBLISHED WHOLLY OR IN PART WITH APPROPRIATION FROM THE RUMFORD FUND.

XXIII.

CONTRIBUTIONS FROM THE PHYSICAL DEPARTMENT OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

XVII.—PHOTOGRAPHY OF THE INFRA-RED REGION OF THE SOLAR SPECTRUM.

By WILLIAM H. PICKERING.

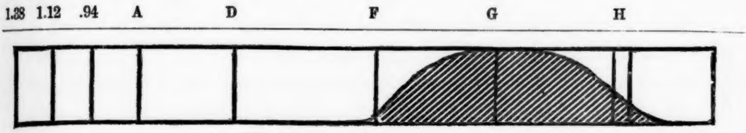
Communicated May 14, 1884.

It has been generally assumed, and indeed distinctly stated by Abney and some others, that the gelatine dry plate is insensitive to that region of the spectrum lying beyond A. On trial, however, this proved not to be the case, as the following results distinctly show. It was found that there was a great difference in the plates, those made by Allen and Rowell, and those by Walker, Reid, and Inglis, giving the best results, the latter being somewhat better than the former. This result was indicated by experiments on the sensitiveness of the plates to daylight and gas-light, — the two abovementioned kinds being the most sensitive of all to the latter, while only moderately so to the former light. The object of the research was to determine to how great a wave-length the plates were sensitive, rather than to obtain a good representation of the lines. A very broad slit was therefore used, and a camera lens of large diameter and short focus. The condensing lens, collimator, and camera lens were each 10 cm. in diameter, and the last of 30 cm. focus. The first two lenses were each of about 90 cm. focal length. The prism measured 10 cm. on a side, and had a refracting angle of 30°. It was so placed that the rays struck the first surface at a slightly oblique angle, thereby obtaining a dispersion equal to that which would be had ordinarily with a 60° prism, and employing only half the thickness of glass. The camera lens had an angular aperture of 19°, and the slit, as usually used, of 1′ 20″. It should be stated here, however, that in the earlier experiments, made with a common spectroscope, using the object-glass of the

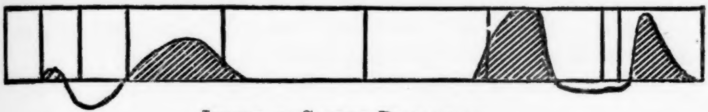
telescope as a camera lens, results were obtained which compared very favorably with those reached with the larger instrument. The prism was composed of dense yellow flint glass, and experiments with specimens of ordinary flint and crown glass 7 cm. in thickness gave no more absorption in the infra-red spectrum, as far as observed, than they would in the visible portion; which is entirely contrary to the general belief. An absorptive medium was placed in front of the slit, in order to destroy all light save that of the wave length which it was desired to photograph. This precaution is necessary, as, owing to the reflections from the surfaces of the lenses and prism, a certain amount of diffused light finds its way to the plate, together with the spectrum, and should this diffused light be of short wave-length, it would fog the plate and the spectrum image would be destroyed. It is also necessary to coat the back of the plate with black varnish, in order to prevent the formation of a halo, owing to reflections from the back of the plate. The absorptive medium consisted either of two pieces of red copper glass, or of a piece of red and a piece of blue glass, or of a thin layer of asphalt varnish on glass, of such density as to be slightly lighter than the combined red and blue glass. These all gave about equally good results, with possibly a slight advantage in favor of the asphalt. Other media were experimented upon, including red glass (single, triple, and quadruple), iodine dissolved in carbon bisulphide, lampblack, and hard rubber.

The iodine solution (see diagram) transmitted a large quantity of light in the vicinity of the H lines, — so much, in fact, as to reverse the spectrum in that region. The lampblack showed a slight broad absorption band between F and G, with a maximum at G. Otherwise the spectrum was quite uniform between A and H, and faded away at the two ends, disappearing at wave-lengths .37 and .94 micron. If one wished for a photograph of the visible spectrum only, it would seem as if it might be obtained very satisfactorily by merely inserting a piece of smoked glass in front of the slit. The glass should be smoked until it is about as dark as two pieces of ordinary red and blue glass placed together appear when viewed by transmitted light.

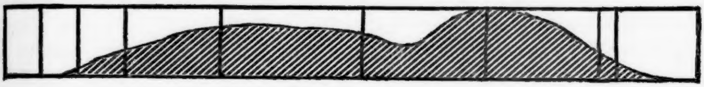
The hard rubber spectrum was obtained with a piece of rubber about .025 cm. in thickness. One could readily see the sun through it, and by close examination detect the window bars when no light came over the shoulder. In structure it was not transparent, but translucent like porcelain, and filled with little irregularities, consisting of short, narrow, opaque lines, lying in the direction in which the sheet had been rolled. On placing it in front of the slit, its spec-



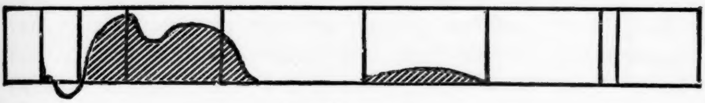
No Medium Interposed.



Iodine in Carbon Disulphide.

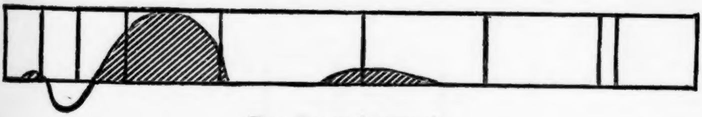


Lampblack.

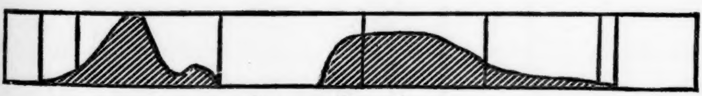


Hard Rubber.

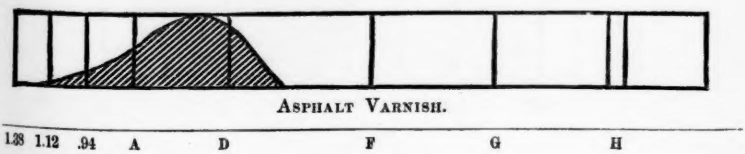
Red Glass.



Red Glass (double).



Red and Blue Glass.

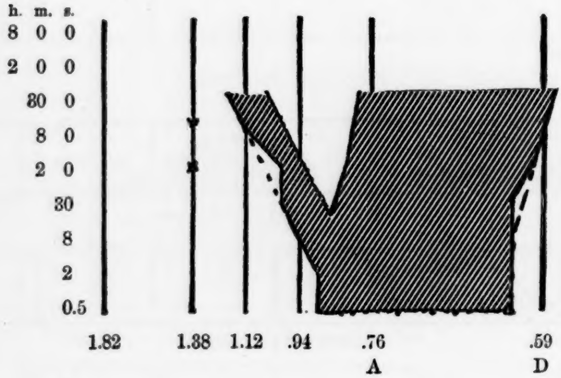


Asphalt Varnish.

trum showed a maximum photographic intensity in the neighborhood of the A line, whence it gradually faded away to line .94, where it reversed, and became direct again near 1.12, where it disappeared. This reversing action was noticed more markedly in the case of the red glass, to be presently described. On the more refrangible side of the A line there was a faint absorption band extending half-way to D, and after that a uniform spectrum till D was reached. Here it began to fall off, and soon disappeared. Between F and G there was a small amount of light transmitted.

With a single red glass there were three maxima, the largest between F and G, the next in size between A and D, and a small one in the neighborhood of the line 1.12 micron. Between the last two maxima there was a reversed band culminating in the neighborhood of line .94. By the insertion of another red glass the maximum between F and G was reduced to a small band in the vicinity of F, and the reversed area was transferred somewhat lower down in the spectrum, so that its maximum occurred near wave-length 1.04. With the red and blue glasses, and with the asphalt, there was apparently no reversed area. The former had three maxima, — at F, just below D, and just above A. The last was the strongest marked, and the one near D was very small. The asphalt had only one maximum, and that was just below D.

If the length of the exposure with two pieces of red glass be increased, the limits of the reversed area will advance in both directions, as is shown by the figure, where abscissas represent the wave-lengths in the prismatic spectrum, and ordinates are proportional to the logarithms of the exposures. The shaded area shows the darkened



portion of the spectrum, while the deep notch represents the reversed portion. This series of exposures was taken on a fairly clear day, but occasionally wave-length 1.38 has been reached in from two to ten minutes, as is shown by the two crosses on the left.

There was a great difference in the transparency of the atmosphere noted on different days. This was noticed by Abney. Strangely enough, quite as good results have been obtained in December as in May and June.

The A line is one of the easiest in the spectrum to photograph, and with the slit 5′ in breadth, it may be taken in one half-second. If the slit is 1′ 20″ wide, the spectrum may any day be photographed as far as wave-length 1.00 in two minutes, and under favorable circumstances as far as 1.38, but beyond that it is not easy to obtain satisfactory results.

INVESTIGATIONS ON LIGHT AND HEAT MADE AND PUBLISHED WHOLLY OR IN PART WITH APPROPRIATION FROM THE RUMFORD FUND.

XXIV.

CONTRIBUTIONS FROM THE PHYSICAL DEPARTMENT OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

XVIII. — METHODS OF DETERMINING THE SPEED OF PHOTOGRAPHIC EXPOSERS.

By WILLIAM H. PICKERING.

Communicated January 14, 1885.

ONE of the best-known methods for this determination depends on photographing a white clock hand, which revolves rapidly in front of a black dial. The chief difficulty in this case is to maintain a uniform rotation at high speed. To avoid this difficulty a method was suggested by me in "Science," Nov. 14, 1884, which depended on photographing a spot of light reflected in a mirror attached to a vibrating tuning-fork. The objection to this plan is that most photographers cannot readily obtain a proper tuning-fork and measure its pitch. Two other methods have therefore been devised in which this difficulty is obviated.

We sometimes see it suggested that, where a true "drop shutter" is used, we may determine its speed by the well-known laws of falling bodies. That this method, if adopted, would give only approximately correct results, is illustrated by the following experiment made with an exposer in which the grooves were of wood, and the shutter itself of hard rubber. The shutter measured 100 cm. (40 inches), in length in order that high speeds might be obtained. It fell apparently perfectly freely, and the friction was reduced to a minimum. The theoretical and measured lengths of exposure are given below, the measurements being made by the method about to be described. The first column gives the distance that the shutter fell before the middle of its aperture reached the middle of the aperture between the lenses. The second column gives the theoretical exposure with a 2.5 cm. aperture; and the third column gives the exposure as measured.

cm.	Theory.	Observed.
76.0	.012	.010
15.0	.029	.025
4.0	.060	.050
2.7	.083	.065

Several observations were made in each case, and it was found that they always agreed with one another within less than ten per cent. The reason why the observed exposures are somewhat shorter (about twenty per cent. in this case) than the theoretical ones is, that even a very brilliant object does not begin to produce a photographic impression upon the plate until quite a large portion of the lens is uncovered. The exposures are therefore somewhat shortened. This effect, which would be added to that of the friction introduced by the style, would seriously interfere with the accuracy of the method published a few months ago, of allowing a tuning-fork to trace a sinusoid on the smoked surface of the drop itself.

It was suggested in the British Journal of Photography, as early as August, 1883, to photograph a freely falling glass ball placed in the sunlight. Applying to this the laws of falling bodies, the exposures may at once be calculated. The suggestion occurs at once that the resistance of the air might be of sufficient importance to vitiate entirely the results thus obtained. In order to ascertain whether this was the case, the following experiment was devised. A glass ball, silvered on the inside, such as is used for Christmas trees, was procured. It measured 4.15 cm. in diameter, and weighed 25 grams. Some white silk threads were attached to a blackened board so as to form a scale of equal parts, and, this being set in the sunlight, the ball was dropped by its side into a box filled with cotton wool. A mirror was attached to the side of a tuning-fork, and the pitch determined. A camera was now placed so as to photograph the image of the ball as seen in the mirror. The fork was set in vibration and the ball dropped. On development, the plate showed a black sinusoidal line, the vibrations of which were near together at the top, but gradually widened out as the ball approached the bottom of its course. Several photographs were taken, and measured under a dividing-engine, with the following results.

As it was impossible to determine the exact time of starting, the nearest point which could be precisely measured was selected. Its distance from the starting-point was called s_1, and the distance of some other point somewhat lower down was called s_2. The distances that would have been traversed if the air had offered no resistance are designated by S_1 and S_2. The number of vibrations executed by the

fork between the starting-point and the points observed is denoted by t_1 and t_2, and the acceleration of gravity during one vibration by g. The distance s_1 in general did not much exceed a centimeter, and the retardation of the atmosphere for this distance could for a first approximation be neglected. The theoretical distance S_2 traversed by the ball will equal

$$S_1 + (2\ S_1\ g)^{\frac{1}{2}}\,(t_2 - t_1) + \frac{g}{2}\,(t_2 - t_1)^2.$$

Substituting s_1 for S_1, we get an approximate value of S_2, from which S_1 may be calculated, and substituted in the above formula. A small correction to the observed distances had to be made, owing to the angular motion of the spot of light on the ball, but this did not exceed two millimeters in any case. From the measurement of five photographs taken on three different days, and with two different arrangements of the ball and scale, it was found that a ball of the above-mentioned size and weight was retarded proportionately to the distance traversed; and that the retardation amounted to exactly .03 of the distance. The maximum fall measured was one meter. This retardation would be proportional to the square of the diameter of the ball, and inversely as its weight; hence we have the equation:

$$\text{Retardation } r = \frac{.03 \times 25}{4.15^2}\,\frac{d^2}{w} = \frac{.0435\,d^2}{w}.$$

It will therefore be seen that for drop-shutter exposures where an accuracy of three per cent is entirely out of the question, we may neglect the retardation of the air entirely, or, better still, counteract it by placing the ball just in front of the scale to be photographed, at .03 of the distance between it and the lens.

Apparatus for Measuring Instantaneous Exposures.

The apparatus which I have adopted as the most convenient for measuring drop-shutter exposures of .05 sec. or less consists simply of a box filled with cotton wool, to the back of which is nailed a vertical slat, 50 cm. in height, painted black, on which, at the intervals given below, are painted fine white horizontal lines, numbered from 0 up to 30. The apparatus is placed in the sunlight, and a glass ball hung by a silk thread is suspended at such a height that when focused in the camera the spot of light upon its surface shall coincide with the

division marked 0. At a given signal the ball is dropped, and the exposer released. A long black line is produced on the plate, and the number of scale divisions that it covers measures the length of the exposure. As the ball requires .3 sec. to reach the bottom, there is no difficulty in catching it on some portion of its course.

In the following table, which was calculated by the formula $s = \frac{gt^2}{2}$, the first column gives the time required by the ball to fall in hundredths of a second; the second, the distance fallen in centimeters; and the third, the distance in inches.

sec.	cm.	in.	sec.	cm.	in.
.00	.0	.00	.18	15.9	6.26
.05	1.2	.48	.19	17.7	6.97
.06	1.8	.72	.20	19.6	7.72
.07	2.4	.94	.21	21.6	8.50
.08	3.1	1.23	.22	23.7	9.33
.09	4.0	1.56	.23	25.9	10.20
.10	4.9	1.93	.24	28.2	11.10
.11	5.9	2.33	.25	30.6	12.05
.12	7.1	2.78	.26	33.1	13.03
.13	8.3	3.26	.27	35.7	14.06
.14	9.6	3.78	.28	38.4	15.12
.15	11.0	4.34	.29	41.2	16.22
.16	12.5	4.92	.30	44.1	17.36
.17	14.2	5.59			

By painting the division marks at these distances, the length of the line made by the ball as photographed on the plate with the scale will give us at once the duration of the exposure in hundredths of a second. Four or five exposures may be made on the same plate, moving the camera slightly after each one. The results obtained will indicate the uniformity of the exposure.

For exposures longer than .05 of a second another method of measurement has been devised. It consists it photographing a seconds pendulum having a silvered glass ball for a bob. The pendulum is placed in the sunlight, and is swung before a painted scale spaced as follows. The scale is constructed on an arc of a circle whose radius is 39 inches, and it is symmetrical on both sides of the middle point. The following distances are measured both ways, starting from the middle, and each space save the last one represents the distance traversed by the pendulum in .02 sec. To traverse the last space requires .1 sec.

	cm.	in.		cm.	in.
Middle point	.0	.00		12.8	5.04
	1.3	.50		13.7	5.41
	2.5	1.00		14.6	5.75
	3.7	1.48		15.4	6.08
	5.0	1.97		16.2	6.38
	6.2	2.44		16.9	6.65
	7.4	2.91		17.5	6.89
	8.5	3.35		18.1	7.13
	9.6	3.78		18.6	7.32
	10.7	4.21		19.0	7.48
	11.8	4.65	The two ends	20.0	7.87

The scale is numbered from one end to the other, and as it takes the bob just one second to traverse the full length, there is plenty of time to measure any short exposure with accuracy. The string of the pendulum is attached to a screw at the top, enabling us to raise the bob. By this means we get several exposures on the same plate. The slight change in the length of the pendulum (an inch or so) makes no appreciable difference in its rate of vibration. By these two methods, involving no complicated apparatus, any exposure, no matter how short, can be readily measured with the greatest accuracy.

INVESTIGATIONS ON LIGHT AND HEAT, MADE AND PUBLISHED WHOLLY OR IN PART WITH APPROPRIATION FROM THE RUMFORD FUND.

XXV.

CONTRIBUTIONS FROM THE PHYSICAL DEPARTMENT OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

XIX. — PRINCIPLES INVOLVED IN THE CONSTRUCTION OF PHOTOGRAPHIC EXPOSERS.

By WILLIAM H. PICKERING.

Communicated January 14, 1885.

THERE are many forms of photographic exposers in use, in this country and abroad, and they differ among themselves in many important particulars. The object of this paper is to determine from theoretical considerations the general fundamental principles which should govern their construction, and to suggest what seems to the writer the best practical form of exposer where very rapid action is desired.

(1.) *Position of the Exposer.* — The exposer may be placed either just in front of the plate, or just back of the lens, or between the lenses, or, finally, just in front of the lens. The former position is that generally employed by astronomers for taking photographs of the sun itself. It has the advantage that, by using a very narrow slit, the observer may make the exposure for any one point as short as he pleases; but different parts of the picture will be taken at different instants, so that, if the body is in rapid motion, the final result will be distorted, and not represent the condition of things at any particular instant. Moreover, this would be an inconvenient position for a shutter in an ordinary camera, and the same remark applies to the second place referred to, — just behind the lens. The usual place is in front of the lens. This position has the advantage of convenience, and in general involves less alteration of the lens-tube than if the exposer is placed between the lenses. On the other hand, it has the disadvantages that it exposes one portion of the plate slightly before the other, and that the shutter has a considerably greater distance to travel, so that, if very short exposures are required, this is a serious

objection. If the exposer is of a form opening and closing from the centre, the central portion of the plate will be longer exposed than the rest, thereby producing a "flare spot," as it is called. But if one is to make a specialty of instantaneous pictures, one lens may be devoted to that work, and a lens-tube constructed for the purpose. The attachment of an exposer properly constructed will not interfere with long exposures. If placed between the lenses, the shutter will be nearer the point of support for the camera, and consequently the jar caused by the exposure will be less. All portions of the plate are exposed at the same instant, and for an equal length of time; hence there is no flare spot produced from this cause. From the above it will be seen that the place presenting the most advantages for the shutter is between the lenses.

(2.) *Construction of the Exposer.* — The exposure is made either by raising a flap, or by causing a single or double slot to pass by the lens. The object of raising a flap is to expose the top of the picture less than the bottom; but sometimes one does not want to expose the top less than the bottom, and there is no more reason for doing so in instantaneous work than with long exposures. Moreover, there are other contrivances for doing this same thing in other ways, as by holding a board in front of the upper part of the lens, etc. In any case it retards the whole exposure more or less. A flap can never be made to work as quickly as a sliding slot, therefore it cannot be used for very rapid exposures; and, moreover, it cannot be placed between the lenses, so that for the ideal shutter it is ruled out. Sometimes a slot is made to open the lens to its full aperture, to stop, and then return the way that it came. If it comes up from below, and is placed in front of the lens, it will evidently give the foreground a longer exposure than the sky, but it cannot be made to work rapidly, and the jar caused by its reversal comes at just the worst possible time, — in the middle of the exposure. The arrangement, therefore, employing the continuously sliding slot, seems to be the best one.

(3.) *Shape of the Aperture in the Exposer.* — The exposure of any shutter may be divided into three parts: that while the shutter is opening, that while it is opened to its full extent, and that while it is closing. Now any bright moving object will begin to form an image soon after the shutter begins to open, and will continue to form one until it is nearly closed. A dark object, on the other hand, will only produce an image during the exposure by the full aperture. But the exposure must be prolonged until the dark object is fully taken; therefore the opening and closing of the shutter must be as rapid as possible in proportion to

that part of the exposure which is with the full aperture. To insure this result, if a slot is made to pass between the lenses, it should be as long as possible in proportion to the diameter of the aperture. The ends of the slot usually have one of the three following forms. They are either semicircular and concave, rectangular, or semicircular and convex.* Sometimes a single slot is used, and sometimes two, which slide past one another in opposite directions. We thus have six methods of opening and closing the aperture, all in common use. Now it is quite evident that all cannot be right, and perhaps the simplest way of studying them will be by the following diagrams. (See page 486.)

At the top of the page are shown the three terminations. The vertical lines underneath show the distances which the shutter would move while four points of the circular aperture between the lenses are being exposed. The points selected are the centre, *c*, the upper extremity of the vertical diameter, *t*, the lower extremity, *b*, and the end of the horizontal diameter, *s*. The shutters are supposed to fall vertically and uniformly, and the first series represents the case where the central vertical dimension of the aperture in the shutter equals the diameter of the aperture between the lenses. If the circular hole passes the lens, the centre of the aperture between the lenses is exposed, while the shutter moves through the diameter of the hole. The top of the aperture is exposed for the same length of time, but its exposure is half over before that at the centre begins. The exposure at the bottom does not begin until that at the top is over. The exposure at the side is merely for an instant, and therefore does not count for anything. If the hole in the shutter were made somewhat larger than that between the lenses better results would be obtained, and the exposures would resemble more nearly those represented in the second figure, with a square aperture. If the shutter were placed in front of the lens, it will now be seen that the bottom of the plate would be photographed before the top, and that distortion would be thereby produced. By placing it between the lenses, however, no trouble of the sort can occur, as every portion of the aperture exposes all parts of the plate at once. With a square slot all portions of the aperture between the lenses receive an equal exposure. With the third form of slot the sides receive double the exposure of the top, bottom, or centre.

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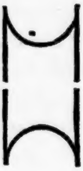
* A diamond-shaped slot is also sometimes used; but this may be considered under the first class.





FIRST SERIES.

(1.) c t b s

(2.) c t b s

(3.) c t b s

SECOND SERIES.

(4.)

(5.)

(6.)

THIRD SERIES.

(7.)

(8.)

(9.)

FOURTH SERIES.

(10.)

(11.)

(12.)

In the second series of lines the slots are supposed to be lengthened out by the insertion of a square between the terminations, so that the length down the middle is now twice the breadth. The only change of importance noticed is, that, while before the full aperture was exposed for an instant only, all the time being occupied in opening and closing the shutter, that now the full opening is exposed for an appreciable interval, equal to one third of the total time consumed. By inserting a rectangle longitudinally, instead of the square, still better results would be obtained. In the third series, two slots similar to those used in the first are supposed to slide past one another in opposite directions. If both are circles, as in the first case, the centre of the aperture between the lenses receives the same exposure as it would if there were only one sliding slot, but the top, bottom, and sides receive only instantaneous exposures. The square slots give a better result, and the third form doubles the exposure at the sides. In the fourth series both slots are supposed to be of similar shape to those used in the second set, and here we find two instances where the full aperture is exposed for half the total time of exposure.

Now since all parts of the aperture between the lenses are of practically equal value, it is evident that the best-shaped slot is that one which lets through the maximum amount of light per unit length of total exposure. That will be the slot which gives the best representation of the dark object, with the least motion of the bright one. The following formulæ represent the amounts of light transmitted by each form of aperture. The third column gives the numerical coefficients of r^3, and the fourth the amount of light transmitted for equal times of exposure. The last figure gives the amount of light transmitted per unit length by the theoretically perfect slot, i. e. one of infinite length, moving with infinite velocity. The fifth column gives the percentages of light transmitted by the various apertures, in terms of the theoretically perfect slot. In comparing the amounts of light transmitted by sliding shutters and by hand exposures, the duration of the former must always be multiplied by the figure in this column corresponding to the form of aperture employed.

(1.)	$\frac{16}{3} r^3$	5.33	2.67	.42
(2.)	$2 \pi r^3$	6.28	3.14	.50
(3.)	$(4 \pi - \frac{16}{3}) r^3$	7.24	3.62	.58
(4.)	$(2 \pi + \frac{16}{3}) r^3$	11.61	3.87	.61
(5.)	$4 \pi r^3$	12.56	4.19	.67
(6.)	$(6 \pi - \frac{16}{3}) r^3$	13.52	4.51	.72
(7.)	$\frac{8}{3} r^3$	2.67	2.67	.42
(8.)	$(2 \pi - \frac{8}{3}) r^3$	3.61	3.61	.57
(9.)	$(4 \pi - 8) r^3$	4.57	2.28	.36
(10.)	$(2 \pi + \frac{8}{3}) r^3$	8.95	4.48	.71
(11.)	$(4 \pi - \frac{8}{3}) r^3$	9.90	4.95	.79
(12.)	$(6 \pi - 8) r^3$	10.85	3.62	.58
			6.28	1.00

It will be noted that the exposures Nos. 1, 2, 3, 9, 10, and 11, as shown by the diagrams, last each for two units of time, and may therefore be readily compared with one another. No. 3 lets through the greatest amount of light for any single slot (.58), and No. 11 for a double slot (.79). These are therefore the best forms to use, and if their lengths can be increased in proportion to their breadths so much the better. No. 11 is the better of the two, but presents more mechanical difficulties of construction when high speeds are desired. With No. 8 the exposure is only one half that of No. 11, but its coefficient is somewhat less (.57). This is only a modified form of No. 11, and with No. 7 gives the shortest exposure of any aperture that uncovers the full size of the lens. The ideal practical shutter will then have an aperture of the form No. 3, 8, or 11, as the case may be, and as much lengthened as possible.

(4.) *Motive Power.* — Now as to the driving force to be employed. It has been found that, with a very sensitive plate (Allen and Rowell extra-quick, or the Stanley) and a rapid rectilinear lens, an exposure of $\frac{1}{200}$ sec. was sufficient to make a fair printing negative. The ideal shutter should then give a minimum exposure of not more than $\frac{1}{200}$ of a second and a maximum of perhaps $\frac{1}{2}$ a second. Let us suppose that the aperture between the lenses is one inch in diameter. The slot, if single, must then be capable of moving with a maximum velocity of two inches in $\frac{1}{200}$ of a second. Theoretically this could be obtained by the force of gravity alone only by a fall of sixteen feet. But a shutter of these proportions is evidently out of the question; therefore, for rapid exposures one must resort to springs. These are of three kinds, — india-rubber, metallic coiled, and metallic spiral. The former are convenient and cheap, but cannot be relied upon to give uniform results. Coiled springs, after they are wound up

two or three turns, unwind with a nearly constant velocity, so that, if there is to be much variation in the exposures, (for example, a ratio greater than 1 to 3 or 1 to 4,) we must resort to complicated gearing. For those who are satisfied with these small ratios and comparatively long exposures, as those who are engaged in photographing yachts exclusively, a coiled spring leaves little to be desired, as it is compact and readily carried. On the other hand, if one wishes to vary the exposure through a large range, such as 1 to 100, or to get an exposure of less than $\frac{1}{50}$ of a second, the drop-shutter arrangement offers peculiar advantages.

Such a shutter has been constructed in which the drop is four inches and the diameter of the aperture seven eighths of an inch; but by attaching two two-inch brass spiral springs beneath it, and doubling the velocity by means of a pulley, the speed has been increased from $\frac{1}{20}$ sec. to $\frac{1}{200}$ sec. The tension of the springs may be adjusted, and any intermediate exposure given. A string which is attached to the top of the shutter passes over a pulley, and has a twenty-gram weight fastened to its other end. This exactly balances the shutter when the springs are released, permitting it to remain motionless in any position. This is desirable for focusing, and also for hand exposures. By thus counterbalancing the weight of the shutter, removing the brass springs and pulley, and attaching small weights in their place, the length of the exposure may be increased from $\frac{1}{20}$ sec. to $\frac{1}{2}$ sec. A shutter constructed on these principles has been in use by me now for some months, and works admirably. The exposures under similar circumstances can always be relied on, and never vary among themselves more than ten per cent. Its total weight does not exceed a pound, and it can instantly be adjusted to give any exposure from $\frac{1}{200}$ to $\frac{1}{2}$ second, or to give hand exposures.

INVESTIGATIONS ON LIGHT AND HEAT, MADE AND PUBLISHED WHOLLY OR IN PART WITH APPROPRIATION FROM THE RUMFORD FUND.

XXVI.

CONTRIBUTIONS FROM THE PHYSICAL LABORATORY OF HARVARD UNIVERSITY.

ON A NEW METHOD FOR DETERMINING THE MECHANICAL EQUIVALENT OF HEAT.

By A. G. WEBSTER.

Communicated by Professor Trowbridge, May 26, 1885.

IN 1867 Joule published the results of his experiments for determining the mechanical equivalent of heat, by means of observations on the thermal effect of an electric current. In his experiments a calorimeter was used holding over a gallon of water, the temperature of which was taken by a thermometer. The method about to be described differs from Joule's in that the temperature is measured by the change of resistance of a wire, which is heated by a current, and no water is employed. The idea of the method was suggested by Professor John Trowbridge. Accuracy is not claimed for the results which follow, as the experiments were undertaken only with the view of ascertaining the practicability of the method.

The method of conducting the experiments was as follows. A thin ribbon of steel about 45 cm. in length and 1 mm. in breadth, and weighing .23 gr., was included in one side of a Wheatstone's bridge, by which its resistance was measured. It was then thrown into another circuit, and a transient current from twelve large Bunsen cells was passed through it. The quantity of electricity transmitted was measured by a ballistic galvanometer, and the difference of potential of the ends of the steel strip was compared with the electromotive force of a Daniell's cell by means of a quadrant electrometer. The rise in temperature of the steel was found by immediately measuring its resistance again. It had been previously found, by a series of experiments made between the temperatures of 90° and 10° C., that the resistance of the steel used was represented by the equation

$$R = a(1 + .00503\,\theta),$$

θ being the temperature.

If then R_0 be the initiaı resistance of the strip, and R_1 the resistance after the passage of the current,

$$R_0 = a\,(1 + \beta\,\theta_0),$$
$$R_1 = a\,(1 + \beta\,\theta_1),$$

and the rise in temperature is

$$\theta_1 - \theta_0 = \frac{R_1 - R_0}{a\beta}$$

If w be the weight of the strip, and s its specific heat, the quantity of heat imparted to it by the current, is

$$h = w\,s\,(\theta_1 - \theta_0) = \frac{w\,s\,(R_1 - R_0)}{a\,\beta}\,. \qquad (1.)$$

But if Q is the quantity of electricity transmitted, and E the difference of potential between the ends of the strip,

$$J h = Q\,E,$$

where J is the mechanical equivalent of heat. We have

$$Q = \frac{H\,T}{G\pi}\;2\sin\frac{a}{2}\,, \qquad (2.)$$

where a is the first swing of the needle of the ballistic galvanometer, G the galvanometer constant, T the period of a single vibration of the needle, and H the horizontal component of the earth's magnetic force. G was determined by comparison of the deflections on the scale of the ballistic galvanometer with the readings of a tangent galvanometer whose constant was calculated, included in the same circuit. In the experiments, $2 \sin \frac{a}{2}$ was considered as proportional to δ, the deflection on the scale, and the value of G for $\delta = 1$ cm. was found to be 769.4. A shunt was used with the galvanometer, so that the value of Q above given is to be multiplied by $\frac{r + S}{S}$, r being the resistance of the galvanometer, and S that of the shunt.

The arrangement of the apparatus was as follows: —

R. The steel strip enclosed in a glass tube to protect it from draughts of air.

W. Wheatstone's bridge.

G_1. Thompson astatic galvanometer.

S_1. Shunt for the same.

G_2. Ballistic galvanometer.

S_2. Shunt for the same.

E. Quadrant electrometer.

B_1. Battery of twelve Bunsen cells.

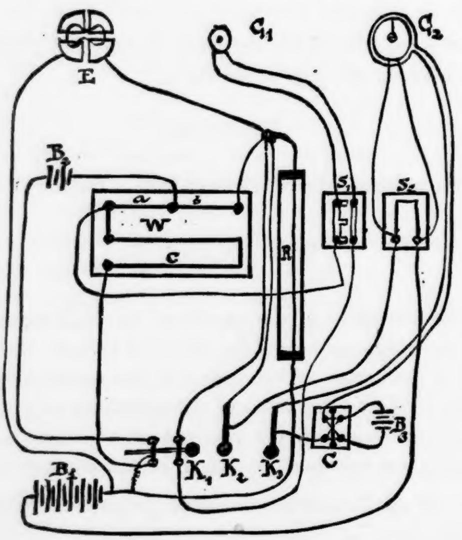
B_2. Battery of two Leclanché cells.

B_3. Do. do. do.

K_1. Key for battery B_2 and galvanometer G_1.

K_2. Key for passing current from B_1 through strip.

K_3. Key in auxiliary circuit with commutator *C*, and a second coil of galvanometer G_2, for bringing the needle quickly to rest without heating strip *R*.



The two galvanometers were arranged to throw their spots of light on the same scale. The key K_1 was first depressed, *R* being then in the bridge circuit, and the spot of G_1 was brought to zero by adjusting the resistance *c*. *a* was always 1,000 ohms, and *b* one ohm. On K_1

being raised, a sufficient extra resistance was inserted in c, so that when K_2 was momentarily depressed, and K_1 was immediately afterwards again depressed, the spot G_1 did not move. The hand soon became accustomed to pressing K_2 just long enough to accomplish this result. In the experiments, c had to be increased from 1,167 ohms by the amount of 50 ohms, and the temperature of the strip accordingly rose about ten degrees. As the resistance was measured almost simultaneously with the passage of the current, the rise in temperature could be very exactly known, and the effect of radiation could be very easily determined.

Combining equations (1) and (2), we have

$$J = \frac{E H T}{G \pi} \delta \frac{(r + S)}{S} \frac{a \beta}{w s (R_1 - R_0)}.$$

E, as measured by the electrometer, was about one volt, $= 10^8$ C. G. S. units. H was .171; r, the resistance of the ballistic galvanometer, was 3,296 ohms; S_1, the shunt, was 1,025 ohms; T, the time of a single vibration of the needle, was 12.6 sec.; a, the resistance of the strip at 0°, was 1.072 ohms; β was .00503, the weight of the strip was .230 gr.; its specific heat, .114; the gain in resistance of the strip was .05 ohm, and δ, from twenty experiments, was 26.8 cm. G was 769.4 for $\delta = 1$.

$$J = \frac{10^8 \times .171 \times 12.6 \times 26.8 \times 4.321 \times 1.072 \times .00503}{769.4\, \pi\, .05 \times 1.025 \times .230 \times .114}$$
$$= 4.14 \times 10^7 \text{ ergs per gram-degree.}$$

In Joule's experiments, the process of heating was continued for nearly an hour, whereas here it lasts for less than a second. In the former method, it was necessary that the current should remain sensibly constant throughout the experiment, and the calorimeter was radiating heat throughout that time. In the short time required by the latter method, the radiation must be very small, and the error from the inconstancy of the current is avoided. I intend to undertake a further course of experiments in order to obtain an accurate determination, the purpose of the present paper being merely to show the method.

JEFFERSON PHYSICAL LABORATORY.

INVESTIGATIONS ON LIGHT AND HEAT, MADE AND PUBLISHED WHOLLY OR IN PART WITH APPROPRIATION FROM THE RUMFORD FUND.

XXVII.

CONTRIBUTIONS FROM THE PHYSICAL LABORATORY OF HARVARD UNIVERSITY.

A STANDARD OF LIGHT.

BY JOHN TROWBRIDGE.

Communicated May 26, 1885.

THE discussions in the Paris Conference of 1881–84 upon the subject of a standard of light, which resulted in the adoption of the light emitted by a surface of platinum at the point of solidification, seemed to assort ill with the discussions which led to a reaffirmation of the value of the C. G. S. system of absolute physical units, and a recognition of the relations between work and heat, and electrical energy.

The solidification point of platinum may be a fixed point in nature; but it has not been shown how this fixed point can be connected with that great web of physical measurements which has been woven by Weber, Helmholtz, Thomson, Maxwell, and other physicists. It is true that during the discussions of the Conference reference was made to a proposition of Schwendler, that the light emitted by a strip of platinum rendered incandescent by a known electrical current should be taken as a standard. This proposition, however, received little support; and the Conference finally adopted the light emitted by solidifying platinum as a standard.

It seems highly desirable that any standard of light which may be adopted should be connected with the present system of absolute measurements. The suggestion of Schwendler, therefore, seems to merit more attention than it has received. The suggestion of employing the light from a strip of platinum rendered incandescent by an electrical current is really due to Dr. John W. Draper, of New York, who in 1847 enunciated it as follows: "A surface of platinum of standard dimensions raised to a standard temperature by a voltaic current will always emit a constant light. A strip of that metal one

inch long and $\frac{1}{20}$th of an inch wide, connected with a lever by which its expansion might be measured, would yield at 2,000° a light suitable for most purposes." *

It has been urged against this standard that different specimens of platinum will emit different amounts of light with the same difference of potential; and that it would be difficult to carry out a measurement of the light and the strength of the current all at the same instant. With a view to obtaining a knowledge of the practical difficulties in this measurement, I interposed a fine platinum wire between the poles of a battery, and endeavored to measure the light emitted, together with the difference of potential at the extremities of the wire and the amount of current which passed through a tangent galvanometer. The difficulties, however, in using a fine platinum wire with a moderate battery power were great. The wire would fuse before the measurements could be satisfactorily made. I then employed a strip of platinum foil 5 mm. wide, about 5 cm. long, and about .02 mm. in thickness. This was placed in a shunt circuit of a small gram machine in order that if the strip should fuse the Dynamo machine might not race. With the proper speed and a suitable adjustment of resistances, the light from this platinum strip could be maintained very constant.

The strip was placed in a long Ritchie photometer box, which was provided with two mirrors inclined according to the plan of Ritchie. One half of the photometer disk was illuminated by the incandescent strip, and the other half by a sperm candle.

The electrical current was measured by a tangent galvanometer of which the reduction factor was .44 C. G. S. system. The difference of potential at the ends of the strip was measured by a Thomson quadrant electrometer, the deflections of which were compared with that of a Daniell cell, the electromotive force of which was approximately 1.09. A Thomson voltmeter was also used. The indications of this instrument agreed with those of the electrometer. The following table gives the deflections of the instrument.

Deflection of Tangent Galvanometer in Degrees.	Deflection of the Electrometer in Centimeters.	
63	5.3	Light the color of a candle.
61	4.9	
59	4.6	
57	4.3	
54.5	3.8	
53.75	3.4	Light very dull red.

* Scientific Memoirs, p. 45.

One Daniell cell gave a deflection with the electrometer of 1.3 centimeters. The resistance of the platinum strip when cold was .2 of an ohm. It will be seen from the above results that the current varied approximately from 8 to 6 webers, with an electromotive force of from 3.8 to 2.6 volts, while the resistance varied from .47 to .44 of an ohm, the resistance when cold being .2 of an ohm. The range of the indications of the electrical instruments was comparatively small, while the light varied enormously. It is evident that the chief difficulty of this method is in measuring a strong current with accuracy: for an increase in the current represented by a fraction of a degree of the tangent galvanometer will result in a very large increase in the light from the incandescent strip.

I next endeavored to ascertain if a thermal junction enclosed in an Edison incandescent lamp, at the centre of the carbon loop, would be sensitive to changes in the heat radiation of the lamp. It is evident that, if this were the case, the carbon loop might be raised to the same point of incandescence in successive times, assuming that the thermal junction at this point of incandescence receives the same amount of radiant energy. Mr. Edison kindly provided me with a lamp in which one thermal junction of an alloy of iridium platinum and platinum was inserted at the centre of carbon loops. The other junction was placed in ice and water. The thermo-electric force of this combination, however, was extremely feeble. The difficulty of inserting wires of other metals into glass prevented me from carrying this idea further. Instead of the thermal junction, a small loop of extremely fine platinum wire was placed at the centre of a carbon loop in an Edison lamp. This fine wire constituted a bolometer strip and made one branch of a Wheatstone's bridge, it being my intention to place a similar strip in another branch of the bridge, thus making a bolometer. The lamp was placed in a photometer box, and its light was compared with that of a candle as it was raised from a red glow to a light of fifteen-candle power. At the same time the resistance of the fine platinum wire was measured by a Wheatstone's bridge. The following table gives the results.

Resistance of the Strip in Ohms.	Distance of Carbon Lamp from Photometer Disk.	Distance of Candle from Photometer Disk.
14.42	70 cm.	40 cm.
14.45	85 "	40 "
14.55	98 "	40 "
14.62	108 "	40 "

This method seems to be quite sensitive. The change in resistance is large when estimated by the number of ohms necessary to restore a balance to the bridge. It was noticed that at a certain point a comparatively small increase in heat radiations was accompanied by a large change in the amount of light emitted. This phenomenon had been noticed early by Dr. J. W. Draper. One Leclanché cell with five ohms in the circuit beside the resistance of the strip was sufficient to raise the latter to a red heat, and precautions were then necessary to prevent a change of resistance from the heating effect of the battery employed with the Wheatstone's bridge. Being desirous of ascertaining whether the resistance of the platinum wire changed after it had been heated to a red heat and had been allowed to cool, I arranged the resistance of the battery circuit outside the bridge, so that the wire could be raised to a red heat, and then, having quickly weakened the battery circuit, remeasured the resistance of the strip. No difference could be perceived in the resistance of the strip. This illustrated the fact discovered by Professor Langley, that thin strips of metal arranged as bolometer strips give up heat very quickly.

The results of this experiment led me to think that a bolometer strip of definite surface could be placed at a fixed distance from a carbon loop of definite dimensions inside an exhausted glass vessel. The amount of radiation which the bolometer strip receives could be calculated; and we might base our standard of light upon the point of incandescence which would give a definite radiation at a fixed distance. We could not distinguish by this method the energy produced by rays of different refrangibility. It seems desirable, however, to substitute for the uncertain estimation of colored lights by the eye an instrument which will measure the energy produced by the radiating source at a certain distance. Within certain limits I found that the bolometer strip would indicate an increase or decrease of the amount of radiant energy received while the difference in color of the incandescent lamp made the observer at the photometer entirely uncertain of his measurements.

Owing to the difficulty of obtaining the proper apparatus for the prosecution of the study of this method, I then studied the question of the practicability of employing a thermopile to measure the amount of radiation from an incandescent strip of platinum at a fixed distance. Within a long photometer box was placed a thin brass vessel containing water. Steam was passed by means of a rubber hose into the water of this vessel which was thus maintained at a constant temperature of about 94° C. The outside of the vessel was about 92° C.

This was ascertained by making the side of the vessel constitute one metal of a thermal junction. Between this vessel and the platinum strip, which was made incandescent by a current of from 8 to 9 webers, was placed a thermopile. The face of the thermopile was thus exposed to the radiation from a given amount of heated surface at a constant temperature, while the other was exposed to the radiation of a given surface of platinum. The faces of the thermopile were provided with the customary cones, and a series of diaphragms of thick card-board extended between the radiating surface of the vessel containing the heated water and the platinum strip. The thermopile was connected with a short coil galvanometer, and was moved until the galvanometer needle came to zero. This arrangement was extremely sensitive, — a movement of a centimeter in the position of the faces of the pile being sufficient to drive the spot of light from the galvanometer mirror off the scale, corresponding to a movement of nearly fifty centimeter scale divisions. There is no difficulty in effecting a balance as quickly as an ordinary photometric measurement is made. While one observer compares a candle or other source of light with the light from an incandescent strip of platinum, another could make the measurements with the thermopile, and could obtain the amount of energy radiated by the incandescent strip in terms of the constant source of heat. It is necessary to reverse the faces of the thermopile, or to place a second constant source of heat on the same side upon which the incandescent strip is placed. The following table indicates the character of the results.

Deflection of the Tangent Galvanometer.	Temperature of Water.	Distance of Face of Pile from Water.	Distance of Face of Pile from Strip.	Remarks.
°	° C.	cm.	cm.	
57.5	95	26.5	49.5	Dull red.
56.5	95	28.0	48	
61	96	25.5	50.5	Bright yellow.
62.5	96.5	24.5	51.5	" "
62.5	96	23.0	53	" "
60.5	97	25.7	50.3	" "
58.5	97.5	26.7	49.3	" "
60	95	24.2	51.8	" "
62.2	94	23.7	52.3	" "

The reduction factor of the galvanometer was .44 in the C. G. S. system. When the photometric indications were the same, the thermopile indicated a large change in the amount of heat received. Thus the heat indications within the range in which the experiments were taken were far more sensitive than the photometric indications.

It seems possible, therefore, to assume as a standard of light an incandescent strip which radiates a definite amount of energy, this energy being measured at a fixed distance which will best agree numerically with the absolute system of measures now universally adopted in heat and electricity. The method of Draper and Schwendler could be combined with the methods I have described above. For a practical standard, a carbon loop in an exhausted vessel raised to such a point of incandescence that it will radiate a definite amount of energy, — this energy being measured by a bolometer strip or the thermopile at a definite distance from the carbon loop, and also being measured by the formula $JH = C^2Rt$, — would have a greater range than an incandescent strip of platinum placed in free air. The latter method, however, for the incandescence which produces a light similar in color to that of a sperm candle, is extremely sensitive, and can be made, I think, more exact than present photometric tests. Both methods have the great advantage of substituting a measure of energy for a relative indication by the eye, which is not connected with any absolute measurement.

These remarks apply to the question of a standard of light for practical purposes, which shall also be scientific in so far that more refined scientific investigation can connect this standard at any time with more precise methods of measuring the exact amount of heat given by radiations of definite wave-length. By means of a Rowland concave grating and with a bolometer strip, one can at present measure the energy of definite radiations. We can say that our scientific standards for light of different colors shall be based upon the energy received upon a definite surface at definite points in the diffraction spectrum.

JEFFERSON PHYSICAL LABORATORY.

PROCEEDINGS.

Seven hundred and seventy-third Meeting.

May 27, 1884. — Annual Meeting.

The President in the chair.

The Corresponding Secretary presented the Report of the Council, which was accepted and ordered to be printed.

The Treasurer and the Librarian presented their annual reports.

On the motion of the Corresponding Secretary, it was

Voted, That, when the Academy adjourn, it adjourn to the second Wednesday in June.

The following gentlemen were elected members of the Academy: —

Alonzo Smith Kimball, of Worcester, to be a Resident Fellow in Class I., Section 3.

Eduard Schönfeld, of Bonn, to be a Foreign Honorary Member in Class I., Section 2, in place of the late Johann Friedrich Julius Schmidt.

The annual election resulted in the choice of the following officers: —

Joseph Lovering, *President.*
Oliver W. Holmes, *Vice-President.*
Josiah P. Cooke, *Corresponding Secretary.*
William Watson, *Recording Secretary.*
Henry P. Kidder, *Treasurer.*
Samuel H. Scudder, *Librarian.*

Council.

Amos E. Dolbear, Robert H. Richards, John Trowbridge,	of Class I.
Asa Gray, Alexander Agassiz, Benjamin E. Cotting,	of Class II.
James B. Ames, Justin Winsor, Andrew P. Peabody,	of Class III.

Rumford Committee.

Wolcott Gibbs, John Trowbridge,
Edward C. Pickering, Josiah P. Cooke,
John M. Ordway, Joseph Lovering,
George B. Clark.

Member of the Committee of Finance.

Thomas T. Bouvé.

The President appointed the following standing committees: —

Committee of Publication.

Josiah P. Cooke, Amos E. Dolbear,
Alexander Agassiz.

Committee on the Library.

Henry P. Bowditch, Henry W. Haynes,
Nathaniel D. C. Hodges.

Auditing Committee.

Henry G. Denny, Robert W. Hooper.

Seven hundred and seventy-fourth Meeting.

June 11, 1884. ADJOURNED ANNUAL MEETING.

The PRESIDENT in the chair.

The Chairman of the Rumford Committee presented the following report: —

The Rumford Committee make the following report for the year ending with the Annual Meeting of May 27, 1884.

The Rumford medals awarded to Professor Rowland at the last annual meeting, were struck at the United States Mint in Philadelphia, and presented at the meeting of the Academy on February 8th.

The experiments in photographing on dry plates, authorized by the Committee, have been continued under the direction of Professor Pickering by Mr. W. H. Pickering, and the results have been communicated to the Academy.

The rich collection of observations in stellar photography left by our late associate, Mr. Henry Draper, has been printed in the Proceedings, under the direction of Professor Pickering, from the income of the Rumford Fund.

The long and careful series of observations on the Zodiacal Light, by Mr. Arthur Searle, have also been printed in the Proceedings from the income of the Rumford Fund.

The Committee have also approved of the expenditures incurred by the Librarian, so far as the additions made to the library relate to Light or Heat.

The following summary of charges against the income of the Rumford Fund is appended to the report: —

For the medals	$346.50
" " books	349.82
" printing	428.18
" photographic materials	34.14
Total	$1,158.64

All which is respectfully submitted,

JOSEPH LOVERING, *Chairman.*

The Committee on the Topographical Survey of the State was discharged.

On the motion of Dr. Gray, it was

Voted, To appropriate for the ensuing year: —

For general expenses	$2,200
For publications	2,000
For library	1,200

The following paper was presented: —

On the Use of the Almucantar. By Seth C. Chandler, Jr.

The following papers were presented by title: —

Notes on some North American Species of Saxifraga. By Asa Gray.

A Contribution to our Knowledge of Paleozoic Arachnida. By Samuel H. Scudder.

Papers on Thermo-electricity: I. On the Application of Thermo-dynamics to Superficial Tension and Thermo-electricity. II. On the Thermo-electric Relations of Metals deposited by Electricity in a Magnetic Field. By John Trowbridge and Charles B. Penrose.

On the Application of Photography to Electrical Measurements and to Heat Measurements. By John Trowbridge.

Comparison of Williamstown Right Ascensions of Polar Stars with late Observations made elsewhere. By Truman H. Safford.

Experiments on the Rotational Coefficients in various Metals. By Edwin H. Hall.

Seven hundred and seventy-fifth Meeting.

October 8, 1884. — STATED MEETING.

The PRESIDENT in the chair.

The Corresponding Secretary read the following letters: from Sir William Thomson, enclosing a communication from the Chancellor of the University of Edinburgh, thanking the Academy for sending a delegate to its Tercentenary Festival;

from M. Pasteur, announcing the formation of a committee for the purpose of erecting a statue to the memory of the late Jean Baptiste Dumas, and inviting subscriptions thereto; from Professor E. Schönfeld, acknowledging his election as Foreign Honorary Member; from the Royal Academy of Science at Bologna, inviting the American Academy to be present at the celebration of the fortieth anniversary of the election of Professor Luigi Calori; from the Natural History Society of Chemnitz, inviting members interested to be present at its twenty-fifth anniversary festival; from C. B. Norton, enclosing documents relating to a proposed American exhibition to be held in London in 1886; from the French National Society of Horticulture, announcing the death of its President, M. Lavallé; from Messrs. W. Gray and Lanman, resigning their fellowships in the Academy.

The President announced the death of Messrs. Lepsius, of Berlin, Bentham, of London, and Pattison, of Oxford, Foreign Honorary Members; and of Alpheus S. Packard, of Brunswick, Maine, Associate Fellow.

On the motion of the Corresponding Secretary, it was

Voted, To adjourn this meeting to the second Wednesday in November.

Remarks on increasing the interest and efficiency of the meetings of the Academy were made by Messrs. Cooke, Edmands, and Trowbridge, and, on the motion of Professor Gray, it was

Voted, That the next meeting of the Academy be held at "the Philosophy Chamber in the University of Cambridge," or such other room as may be convenient.

The following papers were presented: —

On a New Form of Polarimeter and Photometer. By Edward C. Pickering.

On the Motion of the Aar Glacier. By Samuel H. Scudder.

Remarks on the papers were made by the President and Messrs. Cooke and Watson.

Seven hundred and seventy-sixth Meeting.

November 12, 1884. — ADJOURNED STATED MEETING.

The Academy met at the Chemical Laboratory of Harvard College, Cambridge.

The PRESIDENT in the chair.

The President announced the death of Edward Jarvis, of Dorchester, Resident Fellow.

The following gentlemen were elected members of the Academy: —

Benjamin Osgood Peirce, of Cambridge, to be a Resident Fellow in Class I., Section 1.

William Leslie Hooper, of Somerville, to be a Resident Fellow in Class I., Section 3.

Harold Whiting, of Cambridge, to be a Resident Fellow in Class I., Section 3.

William Morris Davis, of Cambridge, to be a Resident Fellow in Class II. Section 1.

Edward Laurens Mark, of Cambridge, to be a Resident Fellow in Class II., Section 3.

Cleveland Abbe, of Washington, to be an Associate Fellow in Class II., Section 1.

Adolf Baeyer, of Munich, to be a Foreign Honorary Member in Class I., Section 3, in place of the late Charles Adolphe Wurtz.

Hans Peter Jörgen Julius Thomsen, of Copenhagen, to be a Foreign Honorary Member in Class I., Section 3, in place of the late Jean Baptiste André Dumas.

Heinrich Ernst Beyrich, of Berlin, to be a Foreign Honorary Member in Class II., Section 1, in place of the late Joachim Barrande.

François Jules Simon, of Paris, to be a Foreign Honorary Member in Class III., Section 3, in place of the late François Auguste Alexis Mignet.

The following papers were presented: —

On the Conversion of Isocyanates into Mustard Oils. By Arthur Michael and G. M. Palmer.

On some Properties of Phenyl-sulphone-acetic Ether. By Arthur Michael and G. M. Palmer.

On Isometric Asparginic Acids. By Arthur Michael and J. F. Wing.

The Synthesis of Methyl-arbutin and Analogous Glucosides. By Arthur Michael.

On Pyromucic Acid. By Henry B. Hill.

On the Reduction of Camphor to Borneol. By C. Loring Jackson.

Descriptions of New Species of Cambarus; to which is added a Synonymical List of the known Species of Cambarus and Astacus. By Walter Faxon. (By title.)

Professor Cooke described and exhibited some remarkable twin crystals of Zircon.

Seven hundred and seventy-seventh Meeting.

December 10, 1884. — Monthly Meeting.

The President in the chair.

The Corresponding Secretary read the following letters: from the Chairman of the Committee of the Institute of Mines at Saint Petersburg, informing the Academy that he had sent copies of Bulletins, and requesting an exchange of publications; from the Royal Bohemian Society of Sciences, at Prague, inviting the Academy to send delegates to its centennial festival; from the Society of Naturalists, at Bamberg, inviting members to attend its semi-centennial festival; from L. Cruls, announcing his appointment as Director of the Imperial Observatory at Rio Janeiro.

The following papers were presented by title: —

Contributions to the Botany of North America. By Asa Gray.

Dictyoneura and the allied Insects of the Carboniferous Epoch. By Samuel H. Scudder.

On the Taconian System of Stratified Rocks. By Jules Marcou.

The following papers were read: —

The Remains at Quiriga, Guatemala: Are they Idols or Memorials of the Dead? By William T. Brigham.

A Determination of the Errors of the Meter made by the Geneva Society for the Construction of Physical Apparatus. By William A. Rogers.

On the Outstanding Errors in the Right Ascensions of Stars of the First and Second Magnitude. By William A. Rogers.

Seven hundred and seventy-eighth Meeting.

January 14, 1885. — STATED MEETING.

The PRESIDENT in the chair.

The Corresponding Secretary read letters from Messrs. Cleveland Abbe, Adolf Baeyer, Alonzo S. Kimball, Jules Simon, and Julius Thomsen, acknowledging election to membership in the Academy.

Professor Cooke announced that the income of the Academy had been increased this year by the remission of the State tax and augmented receipts from some of the investments, the total amounting to about five hundred dollars. It was therefore

Voted, To appropriate an additional sum of five hundred dollars ($500) for the use of the Committee of Publication during the current year.

The following gentlemen were elected members of the Academy: —

Denman Waldo Ross, of Cambridge, to be a Resident Fellow in Class III., Section 3.

Albert A. Michelson, of Cleveland, to be an Associate Fellow in Class I., Section 3.

August Wilhelm Eichler, of Berlin, to be a Foreign Honorary Member in Class II., Section 2, in place of the late George Bentham.

Louis Charles Joseph Gaston, Marquis de Saporta, of Aix,

to be a Foreign Honorary Member in Class II., Section 2, in place of the late Oswald Heer.

Gaston Camille Charles Maspero, of Cairo, to be a Foreign Honorary Member in Class III., Section 2, in place of the late Karl Richard Lepsius.

The following papers were presented: —

Biographical Memoir of the late George Bentham. By Asa Gray.

(*a.*) Photographic Exposers or Drop Shutters. (*b.*) Methods of determining the Speed of Photographic Exposers. By William H. Pickering.

The following paper was presented by title: —

Contributions to American Botany: I. Revision of the Roses of North America. II. Description of some new Species of Plants, chiefly Western. By Sereno Watson.

Seven hundred and seventy-ninth Meeting.

February 11, 1885. — MONTHLY MEETING.

A quorum was not present, and the Academy was not called to order.

Seven hundred and eightieth Meeting.

March 11, 1885. — STATED MEETING.

The PRESIDENT in the chair.

The Corresponding Secretary read the following letters: from the Marquis de Saporta and August W. Eichler, acknowledging their election as Foreign Honorary Members; from Denman W. Ross and Edward L. Mark, acknowledging their election as Resident Fellows; from the Royal Society of Canada, inviting the Academy to send a delegate to be the guest of the society during its annual meeting at Ottawa, beginning on May 19th; from a committee at Pisa, inviting the Academy to be present at the presentation of a gold medal to Professor Menghini; from the Royal Academy of

Sciences at Turin, announcing the conditions under which the Bressa prize will be awarded; also, announcements of the death of Frederick, Count of Stein, and Edouard Henri von Baumhauer.

On the motion of the Corresponding Secretary, it was

Voted, To meet, on adjournment, on the second Wednesday in April.

The following papers were presented: —

On the new Anæsthetic, Cocaine. By Henry W. Williams.

Biographical Memoir of the late Edward Jarvis. By Andrew P. Peabody.

Professor Cooke read the following paper: —

On a Method of Filtration by Means of easily soluble and easily volatile Filters. By Frank A. Gooch.

The following papers were presented by title: —

Observations of Variable Stars in 1884. By Edward C. Pickering.

A Photographic Study of the Nebula in Orion. By Edward C. Pickering.

Notes on some Species of Gymnosporangium and Chrysomyxa of the United States. By William G. Farlow.

Seven hundred and eighty-first Meeting.

April 8, 1885. — ADJOURNED STATED MEETING.

In the absence of the President and the Vice-President, the chair was occupied by Dr. Henry W. Williams.

The Corresponding Secretary called the attention of the Academy to the work entitled, "A Reprint of Annual Reports and other Papers, on the Geology of the Virginias," by the late William Barton Rogers, former Fellow of the Academy; and, on his motion,

Voted, That the thanks of the Academy be presented to Mrs. Rogers for this gift.

The following papers were presented: —

On a new Galvanic Battery and an Incandescent Lamp for Projection. By Amos E. Dolbear.

On the Explanation of various Problems in the Integral Calculus by a Method of Averages. By Harold Whiting.

On the motion of the Corresponding Secretary, it was

Voted, To meet on adjournment at half-past seven o'clock on Wednesday, May 13th.

The following papers were read by title: —

On the Measurement of Length by Means of the Pendulum. By Harold Whiting.

On the Measurement of Length by Means of the Balance. By Harold Whiting.

Seven hundred and eighty-second Meeting.

May 8, 1885. — ADJOURNED STATED MEETING.

The PRESIDENT in the chair.

The Corresponding Secretary read a circular from the French National Society of Horticulture, inviting members of the Academy to participate in the approaching International Congress of Horticulture, to be held at Paris on the 31st of May.

The President announced the death of Samuel Cabot, Robert W. Hooper, and George B. Dixwell, Resident Fellows; and of Carl Theodor Ernst von Siebold, Foreign Honorary Member.

The following gentlemen were elected Members of the Academy: —

Edwin Forrest Sawyer, of Cambridge, to be a Resident Fellow in Class I., Section 2.

Lewis Mills Norton, of Natick, to be a Resident Fellow in Class I., Section 3.

Augustus Lowell, of Boston, to be a Resident Fellow in Class III., Section 3.

Heinrich Wild, of St. Petersburg, to be a Foreign Honorary Member in Class II., Section 1, in place of the late Sir Edward Sabine.

The following papers were presented: —

On the Simultaneous Determination of the Electromotive

Force and Internal Resistance of Batteries. By William L. Hooper.

Contributions from the Physical Laboratory of Harvard University: I. Observations on Atmospheric Electricity. By A. L. McRae, A. McAdie, and John Trowbridge. II. Effect of Temperature on Magnetism. By John Trowbridge and A. L. McRae. III. Standard of Light. By John Trowbridge.

Mr. William H. Pickering exhibited some instantaneous photographs.

The following papers were presented by title: —

Telescopic Search for the Trans-Neptunian Planet. By David P. Todd.

A Comparison of the Observations made between 1860 and 1883 of Stars situated between +70° and +89° Declination, with the Positions of the Harvard College Observatory Catalogue of 1213 Stars. By Anna Winlock.

On the Decomposition of Cinchonine. By Arthur Michael.

Action of Chromic Superfluoride on Benzoic Acid. By C. Loring Jackson and George T. Hartshorn.

A Method of testing colored Media for the Dark Room. By William H. Pickering.

Absolute Sensitiveness of Photographic Dry Plates (continued). By William H. Pickering.

On the Viscosity of Gases. By Silas W. Holman.

REPORT OF THE COUNCIL.

MAY 26, 1885.

During the last year the Academy has lost by death eleven members; — viz. five Resident Fellows: Samuel Cabot, George B. Dixwell, Henry L. Eustis, Robert W. Hooper, Edward Jarvis; two Associate Fellows: Alpheus S. Packard, Benjamin Silliman; and four Foreign Honorary Members: George Bentham, Karl R. Lepsius, Mark Pattison, and Carl T. E. von Siebold.

RESIDENT FELLOWS.

HENRY LAWRENCE EUSTIS.

Henry Lawrence Eustis was born at Fort Independence, in Boston Harbor, on the 1st of February, 1819. His father, Brigadier-General Abraham Eustis, of the United States Army, was graduated from Harvard College in 1804, and received his final title in the regular army in 1834; his mother, who died when he was two years old, was Rebecca, daughter of Dr. John Sprague of Dedham, Mass.

At the age of seven, he was sent to Lancaster Academy, and thence to Stow; he was afterward placed at a boarding school directly opposite West Point. At the age of fifteen he entered Harvard College, and graduated with honors, receiving an oration as his part at Commencement.

He immediately entered the United States Military Academy at West Point, where he at once took the highest rank, and while still a cadet was employed as assistant instructor. He graduated at the head of his class, and in virtue of his scholarship entered the Engineer Corps, receiving his commission as Second Lieutenant in 1842, and entering upon his duties as assistant to the Chief of Engineers at Washington.

In the summer of 1843, he was ordered to Boston as assistant to Colonel Thayer, and served as assistant engineer in the construction of the sea-wall at Lovell's Island, and at Fort Warren in Boston Harbor. From 1845 to 1847, he was the engineer in charge of the works for the improvement of Newport Harbor, consisting of Fort Adams and Goat Island pier, dike, and lighthouse.

From August, 1847, to November, 1849, he was Assistant Professor of Engineering at the United States Military Academy at West Point. This position he resigned to accept the Professorship of Engineering in the Lawrence Scientific School, which had recently been founded.

In 1861 he spent eight months in travelling in Europe for the benefit of his health.

The War of the Rebellion broke out during his absence, and soon after his return, early in March, 1862, he was awakened one night, some hours after retiring to sleep, by the violent ringing of his door-bell. His untimely visitors proved to be Governor Andrew and others, who had come to tell him of the success of the Confederate ram, the Merrimack, and to ask his advice, as an officer of the Engineers, as to the necessity of preparing Boston for the approach of this apparently invincible iron-clad. Soon after this he offered his services to the Governor, and was commissioned Colonel of the 10th Massachusetts Volunteers, August 15, 1862.

His regiment served with the Army of the Potomac in the Maryland campaign from September to November, 1862, being engaged at Williamsport, guarding the Upper Potomac fords, and in the march to Falmouth, Va.; — in the Rappahannock campaign, from December, 1862, to June, 1863, being engaged in operations at the battle of Fredericksburg, the storming of Marye's Height, the battle of Salem, and the passage of the Rappahannock; — in the Pennsylvania campaign, June and July, 1863, being engaged, after a forced march of thirty-five miles, in the battle of Gettysburg, and in the pursuit of the enemy to Warrington, Va.

He was appointed Brigadier-General, September 12, 1863, and took part in the operations in Central Virginia from November, 1863, to March, 1864; being engaged in the combat at Rappahannock Station, Mine Run, and in the march toward Charlottesville and back; — in the Richmond campaign, being engaged in the battle of the Wilderness, the battles around Spottsylvania, and those of Cold Harbor.

General Eustis resigned his command, June 27, 1864, and resumed his duties in the Scientific School with the academic year 1864–65. At this post he remained till his death, there being but six in the active

service of the University whose names, arranged in the order of collegiate seniority, preceded his in the roll of the officers of instruction and government.

During the past two years Professor Eustis had been known to be in failing health. Unwilling, however, to relinquish his classes, his devotion to which was most uncommon, he was forced to ride the short distance to the School, and finally to have his students come to him. At last, however, his strength failed, his physicians sent him to Fernandina, and his return was the result of the knowledge that death was inevitable and near at hand. On Sunday morning, January 11, 1885, he died at his residence in Cambridge, greatly lamented by all his friends and pupils.

Professor Eustis contributed to the Memoirs of this Academy a paper on the Tornado of August 27, 1851. The following brief extract from this paper forcibly illustrates the condition of Meteorology at that time, as contrasted with its present advanced state.

"The work of furnishing the material which shall, when properly elaborated, form the solid and enduring structure of the true science of meteorology is hardly begun. Storms of more or less violence are constantly occurring, but they come without warning, and leave behind them evidences, not only of their own desolating power, but of man's ignorance, which prevented him from anticipating and guarding against them. How many millions of dollars, and how many valuable lives, would be annually saved if we had that precise knowledge which could tell us with the voice of recognized authority that the storm is approaching, and that the ship which we are so joyfully cheering on her way is doomed to destruction if she leave the port! Nay, more, we may deny even the possibility of prediction, and assume merely a knowledge of the mode and sphere of action of storms, and even this shall enable the mariner to direct his course with judgment and escape their fury, instead of running, under false theories, into the very vortex of ruin. If the storm be not a solitary exception to those general laws which govern our physical world, — laws whose beauty, harmony, universality, and mutual dependence Science is every day more and more demonstrating, — then it is not unreasonable to suppose that the time will come when its laws shall be so far made known that the wayfarer on the mighty deep shall be able to escape from the approaching hurricane, with the same certainty and decision with which we now move out of the track of the rushing locomotive engine."

His description of the path of the tornado is given as follows: —

"Emerging from a thicket of forest growth, near the foot of Wel-

lington Hill, in Waltham, the storm crosses an open meadow, and commences the ascent of the hill. Then it passes along the crest of the hill, meeting in its way houses and barns, orchards, cornfields, fences, and forests. Now it commences its descent, and, as if gathering fresh strength at each obstacle, flies with resistless violence through the town beneath, bathes its weary wings in the waters of Spy Pond, cools its feverish breath by the demolition of an ice-house, and with renewed vigor speeds its way through the heart of West Cambridge, over the plain to the Mystic River."

This paper was accompanied by a map of the path on a scale of an inch to one hundred feet: it indicated the position of every tree as determined by two rectangular co-ordinates, and also the direction in which it lay upon the ground. A mere glance at the map shows that the trees point inward toward the axis of the path, so that at almost any point a person may put his finger on the axis line. Nothing was, however, put down on the map which did not present itself in the actual survey, thus leaving everything open to the theories of others.

We now come to Professor Eustis's most important work, a work which has endeared him to a great body of scientific men, professors, and engineers, who owe their success in life to his skilful and devoted labors as a teacher. He was said to be a recluse during the latter part of his life, but the truth is, he devoted all his leisure time to the systematic preparation and arrangement of his instruction.

The method of this instruction is thus described by Professor Whitaker:—

"I cannot say too much of the interesting, valuable, and systematic method by which Professor Eustis has reduced the necessary routine of his work to a minimum, and economized the time of his students in the class-room, insuring the attention of successive classes to the same carefully selected fundamental points, and the thorough examination of the students as a part of the teaching, without dispensing with, or losing to any extent, the advantageous results of oral teaching.

"Without going very much into detail, I may say that for each subdivision of the subjects taught by him he has prepared a number of examination questions which frequently are problems requiring solution. Those questions belonging to any one subdivision are of the same grade, and they are practically interchangeable, so that they may, without especial selection, be handed to the different members of the class for solution. Furthermore, they are not to be found in the usual text-books, and cannot therefore be solved from memory. They require that the students shall exercise both their wits and their

mathematical skill. They also require that they shall understand the principles involved sufficiently well to solve the problems readily. The different problems are written upon cards which are similar to those used in library catalogues. The correct solutions of the problems are written upon similar cards, and both the questions and the answers are filed away in proper cases, and in the order in which they are to be used. The Professor is accustomed to meet his classes for several successive exercises, the number of them depending upon the nature of the principles that are to be considered. During these exercises he makes such explanations and suggestions as in his judgment are necessary, in order that the students may understand this entire subdivision of the subject, without questioning them often, but always giving them an opportunity to question him. At the conclusion of each of such a series of lectures, he hands some card of the proper set to each student for solution. The solved answers enable an accurate examination of the results obtained by the students to be rapidly made. The promptness, certainty, and accuracy with which all this is done are very noteworthy. It would be very greatly to the advantage of students if this method of instruction should become wide-spread, instead of exceptional."

It would be beyond the scope of this notice to describe, or even to enumerate, the problems upon the cards above mentioned, or the admirable series of manuscript notes of which his students made such liberal use. I have, however, thought it best to append the following extracts from letters written by two of Professor Eustis's former students, showing their affection for him as a man and their admiration of him as a teacher.

"In this busy community we often fail to express our appreciation of the efforts and labors of those who have left us, having finished their work in this world. In expressing the debt I owe to Professor Eustis, I am sure that I can also speak for scores of men in varied pursuits, scattered over this continent, who will join with me in a grateful and loving tribute.

"Thirty years ago I came to Harvard University full of a desire for a scientific education, albeit somewhat disheartened by never having been stimulated by a great teacher. I shall never forget my first recitation to Professor Eustis. Having learned my lesson and delivered it in what I considered a perfect manner, I was surprised by a sharp thrust from the gentlemanly man, with military yet modest bearing, who presided over the section. This thrust completely demolished my superficial and egotistical structure, and showed

me where I was weak. He taught me, as no one ever had before, what was true economy in teaching and intellectual effort. I grew to appreciate and love the man who gave the best powers of an unusually strong and disciplined mind to correcting the intellectual processes of a green lad. He taught with his whole body and soul, and, even in these latter days, while occupying a lecture-room near his, I have heard him for two hours at a stretch arguing with those who, convinced, could argue still, turning the subject about with masterly skill so that no one should leave his presence with a muddy brain. There was something pathetic in the tones of that voice, not cushioned by any indolent tutor's ease. There was no space between that voice and the heart. The whole man spoke with it. That voice has literally been worn out in the service of the University for more than a quarter of a century; yet the man was not old. While other men achieved popular reputations with, in many cases, a minimum attention to college classes, Professor Eustis gave always his best to those who attended his recitations. His work, silent and unobserved by the world at large, has borne great fruit; for there are hundreds in America occupying prominent positions, trained by him, who will rise up and call him blessed."

"The late Professor Eustis, was a man whose excellence as an instructor deserves public acknowledgment from his pupils. The quality of his teaching was exceptional. The bent of his mind and the thoroughness of the old West Point discipline made him intolerant of half training or superficial knowledge. The early practice of his profession, and afterward constant reading of its literature, kept him up to the level of its best attainment; and he had a lively contempt for the makeshifts and rules of thumb by which many professional men and some instructors try to handle the results of knowledge without the understanding of it. At the same time he could do justice to that native instinct for construction which he called *gumption*, and which in rare instances — much rarer, probably, than is believed — proves a safe bridge for minds for which formulæ have no meaning. His most characteristic qualities were his rare clearness and directness of mind. These, with his freshness and power of presentation, made his teaching luminous, filling any but a very laggard pupil with interest in his subject, and making the way plain. It was a maxim with him that clear thought made clear speech; he would not admit that any one who had a distinct idea should be unable to find distinct expression for it. There could be no better enforcement of this doctrine than the lucidity of his own explanations. He

always went behind his text-books, and it was seldom that he did not let light into the mind of his pupil.

"The charm of a straightforward and genial manner won the confidence of his pupils even before they felt the mastery of his teaching. This made him unusually accessible and correspondingly popular. Interest in the music of the students added to this accessibility. He had been an early leader of the Pierians, and was the one of the instructors to whom years ago the musical clubs would go with a serenade, and be sure of a hearty welcome. So to the friends who attended his funeral there was a fitting touch of pathetic association in the sound of the young men's voices which sang the familiar hymn."

EDWARD JARVIS.

Edward Jarvis, the son of Francis and Melicent Jarvis, was born at Concord, Mass., January 9, 1803. His parents were persons of high character, both as to intelligence and as to moral worth ; and Concord, early in this century, was as remarkable for the strong staple of its manhood and womanhood as it has been of late years for its literary and philosophical culture. Rev. Dr. Ripley and Samuel Hoar were only the best known of a cluster of professional men who not only gave reputation to the town, but exerted a controlling influence over the young people that grew up around them, so that for many years a certificate of birth in Concord was little less than a guaranty of respectable ability and substantial merit. Jarvis was fitted for Harvard College in part at Concord, and in part at the Westford Academy, and graduated in 1826. In college he was a thorough and faithful student, held a good rank in his class, and won only respect and affection from all who were in any way associated with him.

After graduating, he taught school for a little while in Concord, commencing at the same time his medical studies under the tuition of Dr. Bartlett. He afterward became the pupil of the elder Dr. Shattuck, and while with him practised gratuitously among the poor at the west end of Boston. In addition to the required courses of the Harvard Medical School, he attended a full year's course at the University of Vermont. After taking his medical degree at Harvard College in 1830, he established himself at Northfield, Mass., whence he removed to his native town, and thence, in 1837, to Louisville, Kentucky. Returning to Massachusetts in 1843, he took up his residence in Dorchester, which was his home for the remainder of his life.

He had from the first been greatly interested in the treatment of the insane, and shortly after his settlement in Dorchester he began to receive insane patients in his own house. He was singularly successful in this department of his profession, and was so in no small measure by the power of assiduous kindness, in which he was largely aided by his excellent wife. While he was not neglectful of the resources of medical science, or unskilled in their application, he seemed to win his way to the darkened or clouded intellect by pouring through the intervening medium the most calorific rays that could issue from hearts glowing with pity and love. His restored patients carried with them through life only happy and grateful memories of their residence with him, and remained ever afterward his warmly attached friends, his welcome visitors, and some of them his habitual correspondents.

He early commenced the study of statistics with a purely philanthropic purpose. His researches were chiefly confined to subjects bearing on insanity, the conditions and causes of disease, the sources and consequences of intemperance, and the mutual relation and interaction of physical and moral causes and effects. It is claimed for him by those who, like him, have made statistics a science, that he had no superior in that department. His aim always was, not to support a foregone conclusion, but to obtain materials for a substantial basis of opinion and action. He was careful on all subjects not limited in their very nature to cover with his figures a sufficiently large space, time, or both, for accidental variations to disappear, and was most solicitous to do this when an exceptional year or district would be peculiarly favorable to the result that he expected or desired. He prepared in full the report and digest of mortality statistics for the United States census of 1860, and performed important work also for that of 1870. He was for many years President of the American Statistical Association, and represented it in a general convention of scientific statisticians in London, in 1860. To the close of his life he was in correspondence with statisticians in every European country, and by the exchange of documents he had collected a large and valuable polyglot library of statistical science and literature.

He became interested at an early period in the Institution for the Blind and in the School for Idiots in South Boston, took charge of them during the repeated and prolonged absences of Dr. Howe, always devoted to them a large amount of time and labor, and was constantly resorted to by their teachers and care-takers for advice and sympathy. Of the School for Idiots he was for many years, and until his death, the titular Superintendent, — a sinecure office so far as salary was con-

cerned, but becoming so as to service only when increasing infirmity precluded all active duty.

As a physician he had high reputation, and though he retired from general practice midway in life, there were families that would not give him up at his own request so long as he was able to be at their service. He was, however, in one respect, in advance of his time. He had a very limited confidence in drugs, hardly any in alleged specifics; and before the appearance of Dr. Bigelow's "Nature in Disease," and Sir John Forbes's "Nature and Art in the Cure of Disease," * his practice anticipated their theory, and he placed chief reliance, except in emergencies requiring special treatment, on care, diet, and regimen.

He was thoroughly versed in physiology, which he studied especially in its sanitary relations and bearings. Besides essays on particular subjects, he prepared nearly forty years ago a smaller and a larger text-book on physiology for school use; and their merit may be inferred from the fact that, without any effort to promote their circulation, they were adopted at once in a large number of the best schools, and retained their favored place for many years.

His authorship extended over the entire range of subjects embraced in the health of body, mind, and soul. He was a frequent contributor to all the leading literary and medical periodicals, always with a beneficent aim, and always with conscientious care and faithfulness in the treatment of his subjects. In the application of science to public health, to sociology, and to the moral well-being of the community, we probably have had no wiser or more fruitful writer. On many subjects now regarded as of essential moment, he was a pioneer thinker and writer; and on many more he will in time to come be found to have held that position. Had the mind, the research, the study, the patient labor, thus employed, been concentrated on some single great work, it would have secured for him an enduring name, with not a tithe of the service to humanity rendered month after month with reference to what the writer deemed pressing needs and urgent claims.

In 1874 Dr. Jarvis had a paralytic attack, from which he but partially recovered. For two or three years after this he was incapable of continuous labor. But with some measure of returning strength

* Both these authors were in fact anticipated by our associate, Benjamin E. Cotting, M. D., who, in an address delivered before the Norfolk County Medical Society, in 1852, under the title "Nature in Disease," expressed substantially the views of disease and medical treatment which were given to a larger public by Dr. Bigelow in 1854, and by Sir John Forbes in 1857.

he resumed his habits of industry. Besides various contributions to periodicals, he finished, in 1880, a manuscript volume of six hundred and fifty pages, entitled "Traditions and Reminiscences of Concord, 1719–1878"; and in 1883 a similar volume, entitled "Houses and People of Concord, 1810–1820," comprising biographical sketches of "the prominent people who contributed to the advancement of the town." These volumes are deposited in the public library of Concord, and, as they were prepared with the utmost care and accuracy, they will have a permanent historical value.

Dr. Jarvis possessed the highest claims on the reverent and loving memory of all who knew him. His character had its early laid and immovable foundation of Christian faith and principle, and the evangelic beatitudes were the directory of his life. Those who knew him from his boyhood can remember not an act or a word of his that they could wish to have forgotten. It may be doubted whether he ever said an unkind thing to or of any human being. His single aim was the highest usefulness, and that aim not only directed his professional life and guided his pen, but was manifest in all the details of daily intercourse and conduct. He can have had no enemies, and few acquaintances that were not his friends.

Dr. Jarvis died, of no acute illness, but in consequence of the infirmities of old age, on the 31st of October, 1884. His wife, who had been his faithful helper in his entire life-work for more than half a century, died three days afterward, and the funeral service was performed for them both on the 5th of November, in the church, hard by their home, in which they had been for more than forty years constant attendants and communicants.

ASSOCIATE FELLOWS.

ALPHEUS SPRING PACKARD.

Alpheus Spring Packard, an Associate Member of the Academy, died July 13, 1884, in his eighty-sixth year. He was born in Chelmsford, Massachusetts, in 1798. While he was preparing for college, he studied one year at Exeter Academy under the instruction of Dr. Abbot. He was a graduate of Bowdoin College, of the class of 1816. He afterwards taught in Gorham Academy, in Wiscasset, in Bucksport, and in Hallowell Academy. In 1819 he was made Tutor in

Bowdoin College, and in 1824 he became Professor of Latin and Greek in the same institution. He held this professorship until 1865, and during a part of this time (1842–44) he also had charge of the department of Rhetoric and Oratory. During the last twelve years of his life he held the Professorship of Natural and Revealed Religion at Bowdoin; and after the resignation of President Chamberlain, in 1883, until his own death, he was Acting President of the College. He presided at the Commencement exercises on Thursday, July 10, only three days before his death, and at the Commencement dinner on the same day. He made several speeches at the dinner, introducing the guests who were present; and in the evening he held a reception at his house for the graduating class. The next day, Friday, he took a long drive; and on Saturday he went with his family to Squirrel Island, where he died on Sunday. He attended church Sunday morning, and on his way back to the hotel he was attacked with faintness and died in a few minutes.

Professor Packard was identified with the history of Bowdoin College during more than sixty years. He was the teacher of Hawthorne and Longfellow, and of many others of whose names Bowdoin is justly proud. He published an edition of Xenophon's Memorabilia in 1839, which appeared in a revised form in 1841. He edited the works of his father-in-law, Dr. Appleton, formerly President of Bowdoin College, and wrote the Memoir in the first volume. He sometimes contributed to the North American Review, the Bibliotheca Sacra, and other periodicals. In 1869 he received the degree of Doctor of Divinity from Bowdoin College.

BENJAMIN SILLIMAN.

Benjamin Silliman, who died at New Haven, January 14, 1885, was the second of a name which will always be gratefully remembered among the cultivators of physical science in the United States.

His father, whose death in 1864 was noticed in the sixth volume of these Proceedings, was one of the pioneers in developing the study of physical sciences in this country. Becoming a Professor in Chemistry at Yale College at an early age, he kindled by his enthusiastic teaching a taste for experimental and natural science, not only in his own college, but also throughout the country; and by establishing and editing "The American Journal of Science" through a period of twenty-eight years, not only aided and stimulated his countrymen in their scientific labors, but also made their names and work familiar

to men of science abroad. Into the pleasant home which his father had established at New Haven, Benjamin Silliman, Jr. was born, December 4, 1816.

His mother was the daughter of Jonathan Trumbull, Governor of Connecticut from 1798 to 1809. Thus favored in his parentage, the son breathed from the first the scientific atmosphere which surrounded the father; and it is not surprising that he rapidly acquired a large measure of his father's enthusiasm and a strong inclination to scientific pursuits. Graduated at Yale College with the distinguished class of 1837, he immediately became his father's assistant, and the College Laboratory gave him in this position opportunities for experiment and study of which he assiduously availed himself. By the year 1842 he had, without outside help, of which the country afforded then but little, acquired sufficient knowledge of general and analytical chemistry and mineralogy to enable him to instruct others on those subjects, and he received a few pupils in the old Laboratory of the College, — in what would now be called very narrow quarters. One of the earliest of these was Mr. John P. Norton, who studied with him in 1842–43. Another was Mr. T. Sterry Hunt, who began his studies with Mr. Silliman in 1845. In 1846, a memorial to the Corporation of Yale College by himself, adopted and seconded by his father, urging the official recognition and organization of a new department of advanced science, led to the establishment of the "Department of Philosophy and the Arts." The School of Applied Chemistry was organized under this department, and placed in the charge of Mr. Silliman, as Professor of Chemistry as applied to the Arts, and Mr. John P. Norton, as Professor of Agricultural Chemistry. This School was successful from the beginning, and, if not the first, was one of the first schools of practical science connected with any American college. From this beginning grew the Yale Scientific School, which, after the generous gifts of Mr. Sheffield, expanded into the world-renowned Sheffield Scientific School.

Among the six students of the first year after the new organization were three, G. J. Brush, S. W. Johnson, and William H. Brewer, who subsequently became distinguished Professors in the Sheffield Scientific School.

For thus founding and successfully conducting through the days of small beginnings one of the first schools of experimental and applied science in the United States, Professor Silliman is deserving of the highest praise. And this was unquestionably the most important achievement of his life.

Professor Silliman's connection with the Yale Scientific School was interrupted by his removal to Louisville in 1849, where for five years he discharged the duties of Professor of Medical Chemistry and Toxicology in the Medical College of that place. When he returned to New Haven, in 1854, to enter upon instruction in the Academic and Medical Departments of Yale College, recently resigned by his father, the direction of the Scientific School had passed into other hands, but he retained a nominal connection with it until 1869. In 1870 he resigned his connection with the Academic Department of the College, but he retained his connection with the Medical Department until his death.

In 1838, when twenty-two years old, Mr. Silliman became associated with his father in the editorship of "The American Journal of Science and Arts," the Journal being then in its twenty-first year. This arrangement continued until the close of 1845, when the first series of fifty volumes was ended; after which his brother-in-law, Professor James D. Dana, was associated with Mr. Silliman in the editorial duties. Up to the present time, 1885, his name has stood among those of the editors of the Journal now for nearly half a century. Besides devoting a large amount of time to the work of editing, Mr. Silliman published in the Journal more than fifty papers, embracing a large range of subjects. Most of these were descriptions of minerals, chiefly from the chemical side, which present points of great interest. We may mention the paper on Calcareous Corals (1846); on Emerald Nickel, from Texas, Pa. (1847); on the Results of the Optical Examination of the Micas (1850); on Gay-Lussite from near Ragtown, Nevada (1866), in which the occurrence of this mineral in process of formation is described; on Priceite, a new Borate of Lime (1837); on Platinum and Iridosmine at the Cherokee Gold Mine, California (1837); on Tellurium Ores of Colorado (1874); on the Occurrence of Gold with Sheelite in Idaho (1877); on Jarosite in Arizona (1879); on Vanadates, Chromates, and Tungstates in Arizona (1881); and on the Iron Mountain of Durango, Mexico (1882). Of equal interest were his papers on Meteorites, as those of Burlington, N. Y., of Lockport, N. Y., of Texas, of Concord, N. H., and of Shingle Springs, Cal. He also wrote on points in geology and physical optics, on the illuminating powers of gas, and on the photographic effect of the voltaic arc.

On the centennial of the discovery of oxygen gas by Priestley, celebrated at Northumberland, Pa., August 1, 1874, Professor Silliman prepared a full list of American contributions to chemistry up to the

date of the meeting. This was the result of a large amount of labor, and is a valuable historical work. It may be referred to for a complete list of Professor Silliman's papers up to this date.

Professor Silliman was the author of an elementary treatise on Chemistry, and also of a similar work, entitled, "First Principles of Physics, or Natural Philosophy." Both of these works were for a long time very extensively used as text-books throughout the United States, and of the first more than fifty thousand copies are said to have been sold. Soon after the Industrial Exhibition in New York, 1853, during which Professor Silliman had charge of the Chemical, Mineralogical, and Geological Department, he edited, in connection with Mr. Charles R. Goodrich, a large illustrated quarto volume, entitled, "The World of Science, Art, and Industry," and, in 1854, another similar volume, entitled, "The Progress of Science and Mechanism." One of the latest and most important of his literary works was a report to the National Academy of Sciences, as chairman of a committee appointed by them on the subject of the use of Sorghum as a source of sugar; and the last work of his life was a preparation of a biographical notice, for the same Academy, of his late friend and associate, Mr. J. Lawrence Smith.

In the department of Mineralogy Professor Silliman took an especial interest, and, as his means of collecting were large, he accumulated a fine cabinet, which in 1868 was sold to Cornell University, where it bears the name of the Silliman Cabinet. He also, by his gifts and personal exertions, made important additions to the magnificent collection of minerals at Yale College.

During the last twenty years of his life Professor Silliman's great energies were largely devoted to industrial interests of various kinds, and especially to mining. As a mining expert, he travelled often through the extreme length and breadth of the United States, and visited every important mining region both in this country and in Mexico, and his reports on mining interests have been very numerous, and have involved a great amount of work. He was inclined to such work by his mineralogical and mechanical tastes, and by his active habits, as well as from the force of circumstances. If he sometimes made mistakes of judgment, they were the result of an over sanguine and trustful temperament, not sufficiently regulated by the caution which the training of a mining school and the life of a mining camp gives to those who have been bred to the profession of a mining engineer. Certainly no one suffered from the consequences of his mistakes so greatly as himself.

Professor Silliman was a man of exceedingly generous nature and kindly disposition, and he will always be affectionately remembered by his friends. In society he was most genial, and his lively conversation exhibited broad interests and a wide range of general information. He was married in 1840 to Miss Susan H. Forbes, of New Haven, a most accomplished woman, who united with him to make their home exceedingly attractive to a very wide circle of relatives and friends. Their hospitality was unbounded, and was enjoyed by men of science from every quarter of the globe.

Professor Silliman had a fine physique, and his powers of endurance and of work were remarkable. He always enjoyed excellent health until 1880, when he was prostrated for some weeks by heart disease. From this he soon rallied, and, though conscious of a weakened constitution, was able to resume work with his usual energy. His last illness began in October last with a severe return of his heart complaint, complicated by an attack of pneumonia. From that time the decline was slow, but steady, to the end; and the unselfish and whole-souled nature of the man, which marked his entire life, was never more manifest than during his last days.

Professor Silliman was elected Associate Fellow of this Academy, May 28, 1851, and at his death his name was one of the oldest on its list.

FOREIGN HONORARY MEMBERS.

GEORGE BENTHAM.

George Bentham, one of the most distinguished botanists of the present century, and at the time of his death one of the oldest, was born at Stoke, a suburb of Plymouth, September 22, 1800. He died at his house, No. 25 Wilton Place, London, on the 10th of September, 1884, a few days short of eighty-four years old. His paternal grandfather, Jeremiah Bentham, a London attorney or solicitor, had two sons, who both became men of mark, Jeremy and Samuel. The latter and younger had two sons, only one of whom, the subject of this memoir, lived to manhood. George Bentham's mother was a daughter of Dr. George Fordyce, a Scottish physician who settled in London, was a Fellow of the Royal Society, a lecturer on chemistry, and the author of some able medical works; also, of a

treatise upon Agriculture and Vegetation. It was from his mother that George Bentham early imbibed a fondness for botany.

The early part of his life and education was somewhat eventful and peculiar, and in strong contrast with the later. His father, General, subsequently Sir Samuel Bentham, was an adept in naval architecture. At the age of twenty-two he visited the arsenals of the Baltic for the improvement of his knowledge; thence he travelled far into Siberia. He became intimate with Prince Potemkin, by whom he was induced to enter the civil and afterwards the military service of the Empress Catharine. He took part in a naval action against the Turks on the Black Sea, and was rewarded with the command of a regiment stationed in Siberia, with which he traversed the country even to the frontiers of China. After ten years he returned to England, where his inventive skill and experience found a fitting field in the service of the Admiralty, in which he attained the post of Inspector-General of Naval Works. Among the services he rendered was that of bringing to England the distinguished engineer, Isambard Mark Brunel. In the year 1805, General Bentham was sent by the Admiralty to St. Petersburg to superintend the building in Russia of vessels for the British Navy. He took his family with him; and there began the education of George Bentham, in the fifth year of his age, under the charge of a Russian lady who could speak no English, where he learned to converse fluently in Russian, French, and German, besides acquiring the rudiments of Latin as taught by a Russian priest. On the way back to England, two or three years later, the detention of a month or two in Sweden gave opportunity for learning enough of Swedish to converse in that language, and to read it with tolerable ease in after life. Returning to England the family settled at Hampstead, and the children pursued their studies under private tutors. In the years 1812–13, during the excitement produced by the French invasion of Russia and the burning of Moscow, our young polyglot "budded into an author, by translating (along with his brother and sister) and contributing to a London magazine a series of articles from the Russian newspapers, detailing the operations of the armies." In 1814, upon the downfall of Napoleon, the Bentham family crossed over to France, prepared for a long stay, remained in the country (at Tours, Saumur, and Paris) during the hundred days preceding Napoleon's final overthrow; and in 1816 Sir Samuel Bentham set out upon a prolonged and singular family tour, *en caravane*, through the western and southern departments of France. To quote from the published

account from which most of these biographical details are drawn, and which were taken from Mr. Bentham's own memoranda: "The *cortége* consisted of a two-horse coach fitted up as a sleeping apartment; a long, low, two-wheeled, one-horse spring van for General and Mrs. Bentham, furnished with a library and piano; and another, also furnished, for his daughters and their governess. The plan followed was to travel by day from one place of interest to another, bivouacking at night by the road, or in the garden of a friend, or in the precincts of the prefectures, to which latter he had credentials from the authorities in the capital. In this way he visited Orleans, Tours, Angoulême, Bordeaux, Toulouse, Montpellier, and finally Montauban, where a lengthened stay was made in a country house hired for the purpose. From Montauban (the *cortége* having broken down in some way) they proceeded still by private conveyances to Carcassonne, Narbonne, Nîmes, Tarascon, Marseilles, Toulon, Hyères." *

It was in the early part of this tour that young Bentham's attention was first turned to botany. Happening to take up DeCandolle's edition of Lamarck's *Flore Française*, which his mother, who was fond of the subject, had just purchased, he was struck with the methodical analytical tables, and he proceeded immediately to apply them to the first plant he could lay hold of. "His success led him to pursue the diversion of naming every plant he met with." During his long stay at Montauban he entered as a student in the Protestant theological school of that town, pursuing "with ardor the courses of mathematics, Hebrew, and comparative philology, the last a favorite study in after life," and at home giving himself to music, in which he was remarkably gifted, to Spanish, to botany, and, with great relish, to society. Soon after, the family was established upon a property of two thousand acres, purchased by his father in the vicinity of Montpellier. Here he resumed the intimacy of his boyhood with John Stuart Mill, who was five years his junior, and whose life-long taste for botany was probably fixed during this residence of seven or eight months in the Bentham family in the year 1820. About this time Bentham occupied himself with ornithology, and then with entomology, finding time, however, for another line of study; for at the age of twenty he had begun a translation into French of his Uncle Jeremy's Chrestomathia, which was published in Paris some years afterwards, and he soon after translated also the essay on Nomenclature and Classification. This was followed by his own "Essai sur la

* An article in Nature, October 2, 1884, by Sir Joseph Dawson Hooker.

Nomenclature et Classification," published in Paris. This, his original scientific production, was one of some mark, for it is praised by Stanley-Jevons in his recent History of the Sciences.

On attaining his majority, his elder and only brother having died, he was placed in management of his father's Provençal estate, an employment which he took up with alacrity and prosecuted with success, turning to practical account his methodical habits, his indomitable industry, and his familiarity with Provençal country life and language. The latter he spoke like a native. A language always seemed to come to him without effort. Meanwhile his leisure hours were given to philosophical studies, his holidays to botanical excursions into the Cevennes and the Pyrenees. In the year 1823, a visit to England upon business relating to his father's French estate, where it seemed probable that he was to spend his life, was followed by circumstances which gave him back to his native country. He brought to his uncle Jeremy a French translation of the latter's Chrestomathia; he made the acquaintance of Sir James Edward Smith, Robert Brown, Lambert, Don, and the other English botanists of the day; he visited Sir William, then Professor Hooker, at Glasgow, and Walker Arnott, in Edinburgh, and took the latter with him the next summer to France, where the two botanists herborized together in Languedoc and the Pyrenees. Returning to London, he accepted a pressing invitation to remain and devote a portion of his time to the preparation of his uncle's manuscripts for the press, at the same time pursuing legal studies at Lincoln's Inn. He was in due time called to the bar, and in 1832 he held his first and last brief. In that year Jeremy Bentham died, bequeathing most of his property to his nephew. This was much less than was expected, owing to bad management on his uncle's part, and to the extravagant sums spent by his executors in the publication of the philosopher's posthumous works. But it sufficed, in connection with the paternal inheritance, which fell to him the year previous, for the modest independence which allowed of undistracted devotion to his favorite studies. These were for a time divided between botany, jurisprudence, and logic, not to speak of editorial work upon his father's papers relating to the management of the navy and the administration of the national dockyards.

His first publication was botanical, and was published in Paris, in the year 1826; namely, the "Catalogue des Plantes Indigènes des Pyrénées et du Bas Languedoc." To this is prefixed an interesting narrative of a botanical tour in the Pyrenees, and some remarks

upon the mode of preparing such catalogues in order to their greatest utility, — remarks which already evince the wisdom for which he was distinguished in after years. He also reformed and re-elaborated four difficult genera of the district, Cerastium, Orobanche, Helianthemum, and Medicago. His next work was an article upon codification, — wholly disagreeing with his uncle, — which attracted the attention of Brougham, Hume, and O'Connell. It was followed by one upon the laws affecting larceny, which Sir Robert Peel complimented and made use of, and by another on the law of real property.

But his most considerable work of the period received scant attention at the time from those most interested in the subject, and passed from its birth into oblivion, from which only in these later years has it been rescued, yet without word or sign from its author. This work (of 287 octavo pages) was published in London in 1827, under the title of "Outline of a New System of Logic, with a Critical Examination of Dr. Whately's Elements of Logic." It was in this book that the quantification of the predicate was first systematically applied, in such wise that Stanley-Jevons * declares it to be "undoubtedly the most fruitful discovery made in abstract logical science since the time of Aristotle." Before sixty copies of the book had been sold, the publisher became bankrupt, and the whole impression of this work of a young and unknown author was sold for waste paper. One of the extant copies, however, came into the hands of the distinguished philosopher, Sir William Hamilton, to whom the discovery of the quantification of the predicate was credited, and who, in claiming it, brought "an acrimonious charge of plagiarism" against Professor De Morgan upon this very subject. Yet this very book of Mr. Bentham is one of the ten placed by title at the head of Sir William Hamilton's article on Logic in the Edinburgh Review for April, 1833; is once or twice referred to in the article; and, a dozen years later, in the course of the controversy with De Morgan, Sir William alluded to this article as containing the germs of his discovery. We may imagine the avidity with which De Morgan, injuriously attacked, would have seized upon Mr. Bentham's book if he had known of it. It is not so easy to understand how Mr. Bentham — although now absorbed in botanical researches — could have overlooked this controversy in the Athenæum, or how, if he knew of it, he could have kept silence. It was only at the close of the year 1850 that Mr.

* In Contemporary Review, xxi., 1873, p. 823.

Warlow sent from the coast of Wales a letter to the Athenæum, in which he refers to Bentham's book as one which had long before anticipated this discovery. Although Hamilton himself never offered explanation of his now unpleasant position (for the note obliquely referring to the matter in the second edition of his Discussions is not an explanation), Mr. Baine did (in the Athenæum for February 1, 1851) immediately endeavor to discredit the importance of Bentham's work, and again in 1873 (Contemporary Review, xxi.), in reply to Herbert Spencer's reclamation of Bentham's discovery. To this Stanley-Jevons made reply in the same volume (pp. 821–824); and later, in his Principles of Science (ii. 387), this competent and impartial judge, in speaking of the connection of Bentham's work "with the great discovery of the quantification of the predicate," adds: —

"I must continue to hold that the principle of quantification is explicitly stated by Mr. Bentham; and it must be regarded as a remarkable fact in the history of logic, that Hamilton, while vindicating, in 1847, his own claims to originality and priority as against the scheme of De Morgan, should have overlooked the much earlier and more closely related discoveries of Bentham."

It must be that Hamilton reviewed Bentham's book without reading it through, or that its ideas did not at the time leave any conscious impression upon the reviewer's mind, yet may have fructified afterwards.

After his uncle's death, in 1832, Mr. Bentham gave his undivided attention to botany. He became a Fellow of the Linnean Society in 1828. Robert Brown soon after presented his name to the Royal Society, but withdrew it before the election, to mark the dissatisfaction on the part of scientific men with the management of the Society when a Royal Duke was made President. Consequently he did not become F. R. S. until 1862. In 1829, when the Royal Horticultural Society was much embarrassed, he accepted the position of Honorary Secretary, with his friend Lindley as an associate. Under their management it was soon extricated from its perilous condition, attained its highest prosperity and renown, and did its best work for horticulture and botany. In 1833 he married the daughter of Sir Harford Brydges, for many years British Ambassador in Persia, and the next year he tock up his residence in the house in Queen Square Place, Westminster, inherited from his uncle, in which the Benthams, Jeremy and his own paternal grandfather, had dwelt for almost a century. The house no longer exists, but upon its site stands the

western wing of the "Queen Anne mansions." The summer of 1836 was passed in Germany, at points of botanical interest, and wherever the principal herbaria are preserved, — the whole winter in Vienna. Some account of this tour, and interesting memoranda of the botanists, gardens, and herbaria visited, communicated in familiar letters to Sir William Hooker, were printed at the time (without the author's name) in the second volume of the Companion to the Botanical Magazine. Similar visits for botanical investigation, mingled with recreation, were made almost every summer to various parts of the Continent; in one of them he revisited the scenes of his early boyhood in Russia, travelled with Mrs. Bentham to the fair at Nischnii-Novgorod, and thence to Odessa, by the rude litter-like conveyances of the country.

In 1842 he removed with his herbarium to Pontrilas House, in Herefordshire, an Elizabethan mansion belonging to his brother-in-law, and combined there the life of a country squire with that of a diligent student, until 1854, when, returning to London, he presented his herbarium and botanical library to the Royal Gardens at Kew, where they were added to the still larger collections of Sir William Hooker. After a short interval, Mr. Bentham took up his residence at No. 25 Wilton Place, between Belgrave Square and Hyde Park, which was his home for the rest of his life. Thence, autumn holidays excepted, with perfect regularity for five days in the week he resorted to Kew, pursued his botanical investigations from ten to four o'clock, and then, returning, wrote out the notes of his day's work before dinner, hardly ever breaking his fast in the long interval. With such methodical habits, with freedom from those professional or administrative functions which consume the precious time of most botanists, with steady devotion to his chosen work, and with nearly all authentic materials and needful appliances at hand or within reach, it is not surprising that he should have undertaken and have so well accomplished such a vast amount of work: and he has the crowning merit and happy fortune of having completed all that he undertook.

Nor did he decline duties of administration and counsel which could rightly be asked of him. The Presidency of the Linnean Society, which he accepted and held for eleven years (1863 to 1874), was no sinecure to him; for he is said to have taken on no small part of the work of Secretary, Treasurer, and Botanical Editor. Somewhat to the surprise of his younger associates, who knew him only as the recluse student, he made proof in age of the fine talent for business and the conduct of affairs which had distinguished his prime in the

management of the Horticultural Society; and in his annual presidential addresses, which form a volume of permanent value, his discussions of general as well as of particular scientific questions and interests bring out prominently the breadth and fulness of his knowledge and the soundness of his judgment.

The years which followed his retirement from the chair of the Linnean Society, at the age of seventy-three, were no less laborious or less productive than those preceding; at the age of eighty (as the writer can testify) the diminution of bodily strength had wrought no obvious abatement of mental power, and not much of facility; and he was able to finish in the spring of 1883 the great work upon which he was engaged. As was natural, his corporeal strength gave way when his work was done. After a year and a half of increasing debility, he died simply of old age,—the survivor of his wife for three or four years,—the last of the Benthams, for he had no children, nor any collateral descendants of the name.

A large part of his modest fortune was bequeathed to the Linnean Society, to the Royal Society for its scientific relief fund, and in other trusts for the promotion of the science to which his long life was so perseveringly devoted.

The record of no small and no unimportant part of a naturalist's work is to be found in scattered papers, and those of George Bentham are quite too numerous for individual mention. The series begins with an article upon *Labiatæ*, published in the Linnæa in 1831; it closes with one in the Journal of the Linnean Society, read April 19, 1883, indicating the parts taken by the two authors in the elaboration of the Genera Plantarum, then completed. Counting from the date of the Catalogue of Pyrenean Plants, 1826, there are fifty-seven years of authorship. His first substantial volume in botany was the "Labiatarum Genera et Species," or a description of the genera and species of plants of the order *Labiatæ*, with their general history, characters, affinities, and geographical distribution, an octavo of almost 800 pages, of which the first part was published in 1832, the last in 1836. He found even the European part of this large order in much confusion; his monograph left its seventeen hundred and more of species so well arranged (under 107 genera and in tribes of his own creation), that there was little to alter, except as to the rank of certain groups, when he revised them for the Prodromus in 1848, and finally revised the genera (now increased to 136, and with estimated species almost doubled) for the Genera Plantarum in 1876. Although the work of a beginner, it took rank as the best extant monograph of its kind,—one of a

large natural order, without plates. In it Mr. Bentham first set the example, in any large way, of consulting all the available herbaria for the inspection and determination of type-specimens. For this he made journeys to the Continent every year from 1830 to 1834, visiting nearly all the public and larger private herbaria.

In the years during which the monograph of *Labiatæ* was in progress, Mr. Bentham elaborated and published the earlier of the papers which have particularly connected his name with North American Botany. These are, first, the reports on some of the new ornamental plants raised in the Horticultural Society's garden from seeds collected in Western North America by Douglas, under the auspices of that society, by which were first made known to botanists and florists so many of the characteristic genera and species of Oregon and California, now familiar in gardens, — Gilias and Nemophilas, Limnanthes, Phacelias, Brodiæas, Calochorti, Eschscholtzias, Collinsias, and the like; then the monograph of *Hydrophylleæ* (1834), followed the next year by that on *Hosackia* and that on the *Eriogoneæ*, — all American and chiefly North American plants, — the first fruits of a great harvest which even now has not wholly been gathered in, the field is so vast, though the laborers have not been few. Later came the "Plantæ Hartwegianæ," an octavo volume begun in 1839, but finished in 1857 with the California collections; and in 1844, the "Botany of the Voyage of the Sulphur," in quarto, the first part of which relates to Californian botany. The various papers upon South American Botany are even more numerous; one of them being that in which Heliamphora, of British Guiana, a new genus of Pitcher Plants, of the Sarracenia family, was established.

Bentham's labors upon the great order *Leguminosæ* began early, with his "Commentationes de Leguminosarum Generibus," published in the Annals of the Vienna Museum, being the work of a winter's holiday (1836–37) passed in that capital, in the herbarium then directed by Endlicher. This was followed by a series of papers, mostly monographs of genera, in Hooker's Journal of Botany, in the Journal of the Linnean Society, and elsewhere, by the elaboration of the order for the imperial Flora Brasiliensis, and later, by the Revision of the Genus *Cassia* and that of the Sub-order *Mimoseæ*, in the Transactions of the Linnean Society, the latter (a quarto volume in size) published as late as the year 1875. Both are models of monographical work.

An important series of monographs in another and more condensed form was contributed to DeCandolle's Prodromus, namely, the Tribe

Ericeæ in the seventh volume, the *Polemoniaceæ* in the ninth, the *Scrophulariaceæ* in the tenth, the *Labiatæ* forming the greater part of the twelfth, and the *Eriogoneæ* in the fourteenth; these together filling 1133 pages, according to the surviving editor. If not quite the largest collaborator of the DeCandolles, as counted in pages, he was so in the number of plants described, and his work was of the best. It was also ready in time, which is more than can be said of the collaborators in general.

There are few parts of the world upon the botany of which Mr. Bentham has not touched; — Tropical America, in the ample collections of Mr. Spruce, and those of Hartweg, distributed, and the former partly and the latter wholly determined by him, as also Hinds's collections made in the voyage of the Sulphur, besides what has already been adverted to; Polynesia, from Hinds's and Barclay's collections; Western Tropical Africa, in the Niger Flora, most of the *Flora Nigritiana* being from his hand; the *Flora Hongkongensis*, in which he began the series of British Colonial floras; and finally that vast work, the *Flora Australiensis*, in seven volumes, which the author began when he was over sixty years old and finished when he was seventy-seven. Nor did he neglect the cultivation of the narrow and more exhausted field of British Botany. His "Handbook of the British Flora," for the use of beginners and amateurs, published in 1858, has gone through four large editions. Its special object was to enable a beginner or a mere amateur, with little or no previous scientific knowledge and without assistance, to work out understandingly the characters by which the plants of a limited flora may be distinguished from each other, these being expressed as much as possible in ordinary language, or in such technical terms as could be fully explained in the book itself and easily apprehended by the learner. The immediate and continued popularity of this handy volume, bringing the light of full knowledge and sound method to guide the beginner's way, illustrates the advantage of having elementary works prepared by a master of the subject, whenever the master will take the necessary pains. To the same end, the author prepared for this volume an excellent and terse introduction to structural and descriptive botany, which has been prefixed to all the Colonial Floras. In the first edition of this British Flora, it was attempted to use or to give English names to the genera and species throughout. This was possible only in such a familiar and well-trodden field as Britain, where almost every plant is familiar; but even here it failed, and in later editions the popular names were relegated to a subordinate position.

It has been stated that Mr. Bentham was over sixty years old when he undertook the *Flora Australiensis*, and he was seventy-seven when he brought this vast work to completion, assisted only in notes and preliminary studies by Baron von Müller of Melbourne. About the same time he courageously undertook the still greater task of a new *Genera Plantarum*, to be worked out, not, like that of Endlicher, mainly by the compilation of published characters into a common formula, but by an actual examination of the extant materials, primarily those of the Kew herbaria, — this work, however, in conjunction with his intimate associate, Sir Joseph Hooker. This work is the only "joint production" in which Mr. Bentham ever engaged. The relations and position of the two authors made the association every way satisfactory, and the magnitude of the task made it necessary. The training and the experience of the two associates were very different and in some ways complemental, one having the greatest herbarium knowledge of any living botanist, the other being the widest and keenest observer of vegetable life under "whatever climes the sun's bright circle warms," as well as of Antarctic regions, which it warms very little. It would be expected, on the principle "juniores ad labores," that the laboring oar would be taken by the younger of the pair. It was long and severe work for both; but the veteran was happily quite free from, and his companion heavily weighted by, onerous official duties and cares; and so it came to pass that about two thirds of the orders and genera were elaborated by Mr. Bentham. In April, 1883, the completion of the work (i. e. of the genera of Phænogamous plants, to which it was limited) closed this long and exemplary botanical career; and the short account which he gave to the Linnean Society on the 19th of that month, specifying the conduct of the work and the part of the respective authors, was his last publication.

In this connection, mention should also be made of the essays (which he simply calls "Notes") upon some of the more important orders which he investigated for the Genera Plantarum, — the Compositæ, the Campanulaceous and the Oleaceous orders, the Monocotyledoneæ as to classification, the Euphorbiaceæ, the Orchis family, the Cyperaceæ, and the Gramineæ. These are not mere abstracts, issued in advance, but critical dissertations, with occasional discussions of some general or particular question of terminology or morphology. When collected, they form a stout volume, which, along with the volume made up of his anniversary addresses when President of the Linnean Society, and the paper on the progress and state of systematic botany,

read to the British Association for the Advancement of Science in 1874, should be much considered by those who would form a just idea of the largeness of Mr. Bentham's knowledge and the high character of his work.

It will have been seen that Mr. Bentham confined himself to the Phænogamia, to morphological, taxonomical, and descriptive work, not paying attention to the Cryptogamia below the Ferns, nor to vegetable anatomy, physiology, or palæontology. He was what will now be called a botanist of the old school. Up to middle age and beyond, he used rather to regard himself as an amateur, pursuing botany as an intellectual exercise. "There are diversities of gifts." Perhaps no professional naturalist ever made more of his; certainly no one ever labored more diligently, nor indeed more successfully over so wide a field, within these chosen lines. For extent and variety of good work accomplished, for an intuitive sense of method, for lucidity and accuracy, and for insight, George Bentham may fairly be compared with Linnæus, DeCandolle, and Robert Brown.

His long life was a perfect and precious example, much needed in this age, of persevering and thorough devotion to Science, while unconstrained as well as untrammelled by professional duty or necessity. For those endowed with leisure, to "live laborious days" in her service is not a common achievement.

The tribute which the American Academy of Sciences pays to the memory of a deceased Foreign Honorary Member might here fittingly conclude. But one who knew him long and well may be allowed to add a word upon the personal characteristics of the subject of this memorial; the more so, that he is himself greatly indebted for generous help. For, long ago, when in special need of botanical assistance, Mr. Bentham invited him and his companion to his house at Pontrilas, and devoted the greater part of his time for two months to his service. Mr. Bentham's great reserve and dryness in general intercourse, and his avoidance of publicity, might give the impression of an unsympathetic nature. But he was indeed most amiable, warm-hearted, and even genial, "the kindest of helpmates," the most disinterested of friends.

MARK PATTISON.

In the death, on July 30, 1884, of Mark Pattison, Rector of Lincoln College, Oxford, whose name has been upon the roll of our Foreign Honorary Members since 1876, Oxford lost her most erudite scholar, and her most competent critic in many branches of learning.

The son of a Yorkshire clergyman, Pattison was born in 1813. Without having been at a public school, he came to Oxford in 1832, and remained there, with short and infrequent intermissions, for the rest of his life. In his autobiographic "Memoirs," written during the last year of his life, and in full consciousness of its near approaching close, he has left an interesting and candid account of his own intellectual development, of his relations to the University, in which his figure was for more than a generation one of the most eminent, and where he has left no one to occupy a position similar to that which he filled. What he calls "the unconscious instinct of a studious life, having its origin in the days of early boyhood," developed by well-directed, conscientious, and steady training, controlled his whole career. "I have never ceased," he says, in almost his final words, "to grow, to develop, to discover, up to the very last."

He was a vast reader; his scholarship was of wide range, embracing not only proper classical learning, but a thorough acquaintance with the writers and the history of the early Church, with the movement of theological sentiment in modern Europe, and especially the course of religious thought in England, and with the progress of classical learning from the Renaissance down to Niebuhr. Few men had a more exact and extensive knowledge of English literature, particularly of that of the seventeenth and eighteenth centuries. Like most scholars of such wide attainment, he wrote little in proportion to the amount of his acquisitions, but what he wrote was of value in inverse proportion to its extent. His essays on University Reform and Academical Organization, on the Endowment of Research, on the Tendencies of Religious Thought in England from 1688 to 1750, and other papers contributed to various journals, are of enduring worth; but it is by his Life of Milton, by his masterly edition of Milton's Sonnets and of Pope's Essay on Man, and his Life of Casaubon, that he is likely to be best remembered. His conscientious erudition made him a standard to all, and a rebuke to those who were not thorough in their work. Careless workers dreaded him as a judge at once most competent and most merciless. But he applied his criti-

cal faculty to his own work, no less than to the work of others. "I have never," he says, "enjoyed any self-satisfaction in anything I have ever done, for I have inevitably made a mental comparison with how it might have been better done. The motto of one of my diaries, 'Quicquid hic operis fiat pœnitet,' may be said to be the motto of my life."

It had long been his intention to write a Life of Scaliger, for whom, as something more than the first scholar of the modern age, he felt the deepest respect. He imposed it upon himself, "as a solemn duty, to rescue the memory of Scaliger from the load of falsehood and infamy" under which his enemies had contrived to bury it. For nearly thirty years he was getting together the materials for this *vindiciæ*. But the work of completing the composition of the Life was postponed too long, and Scaliger must still await a champion. It will be long before one so well equipped is likely to appear in the lists.

The memory of Mark Pattison will be cherished by scholars, and deserves to endure as that of a student faithful to the high ideals of intellectual life.

Since the last Report, the Academy has received an accession of twenty new members; viz. nine Resident Fellows, two Associate Fellows, and nine Foreign Honorary Members; and four members have withdrawn. The list of the Academy, corrected to the date of this Report, is hereto added. It includes 196 Resident Fellows, 84 Associate Fellows, and 71 Foreign Honorary Members.

LIST

OF THE FELLOWS AND FOREIGN HONORARY MEMBERS.

RESIDENT FELLOWS.—196.

(Number limited to two hundred.)

CLASS I.—*Mathematical and Physical Sciences.*—79.

SECTION I.—7.

Mathematics.

Benjamin A. Gould, Cambridge.
Gustavus Hay, Boston.
Benjamin O. Peirce, Cambridge.
James M. Peirce, Cambridge.
John D. Runkle, Brookline.
Edwin P. Seaver, Newton.
T. H. Safford, Williamstown.

SECTION II.—15.

Practical Astronomy and Geodesy.

J. Ingersoll Bowditch, Boston.
Seth C. Chandler, Jr., Cambridge.
Alvan Clark, Cambridgeport.
Alvan G. Clark, Cambridgeport.
George B. Clark, Cambridgeport.
John R. Edmands, Cambridge.
Henry Mitchell, Boston.
Robert Treat Paine, Brookline.
Edward C. Pickering, Cambridge.
William A. Rogers, Cambridge.
Edwin F. Sawyer, Cambridge.
Arthur Searle, Cambridge.
Leopold Trouvelot, Cambridge.
O. C. Wendell, Cambridge.
Henry L. Whiting, Tisbury.

SECTION III.—43.

Physics and Chemistry.

A. Graham Bell, Cambridge.
Clarence J. Blake, Boston.
Francis Blake, Weston.
John H. Blake, Boston.
Thos. Edwards Clark, Williamstown.
W. S. Clark, Amherst.
Josiah P. Cooke, Cambridge.
James M. Crafts, Boston.
Charles R. Cross, Boston.
William P. Dexter, Roxbury.
Amos E. Dolbear, Somerville.
Charles W. Eliot, Cambridge.
Moses G. Farmer, New York.
Thomas Gaffield, Boston.
Wolcott Gibbs, Cambridge.
Frank A. Gooch, Cambridge.
Edwin H. Hall, Cambridge.
Henry B. Hill, Cambridge.
N. D. C. Hodges, Salem.
Silas W. Holman, Boston.
William L. Hooper, Somerville.
Eben N. Horsford, Cambridge.
T. Sterry Hunt, Montreal.
Charles L. Jackson, Cambridge.
William W. Jacques, Newtonville.
Alonzo S. Kimball, Worcester.
Leonard P. Kinnicutt, Worcester.
Joseph Lovering, Cambridge.
Charles F. Mabery, Cambridge.
Alfred Michael, Medford.
William R. Nichols, Boston.
Lewis M. Norton, Natick.
John M. Ordway, Boston.
William H. Pickering, Boston.
Robert H. Richards, Boston.
Edward S. Ritchie, Brookline.
Stephen P. Sharples, Cambridge.
Francis H. Storer, Boston.
John Trowbridge, Cambridge.
Cyrus M. Warren, Brookline.
Harold Whiting, Cambridge.
Charles H. Wing, Boston.
Edward S. Wood, Cambridge.

SECTION IV. — 14.

Technology and Engineering.

George R. Baldwin, Woburn.
John M. Batchelder, Cambridge.
Chas. O. Boutelle, Washington, D.C.
James B. Francis, Lowell.
John B. Henck, Boston.
E. D. Leavitt, Jr., Cambridge.
William R. Lee, Roxbury.
Frederic W. Lincoln, Boston.
Hiram F. Mills, Lawrence.
Alfred P. Rockwell, Boston.
Charles S. Storrow, Boston.
William R. Ware, New York.
William Watson, Boston.
Morrill Wyman, Cambridge.

CLASS II. — *Natural and Physiological Sciences.* — 58.

SECTION I. — 9.

Geology, Mineralogy, and Physics of the Globe.

Thomas T. Bouvé, Boston.
William T. Brigham, Boston.
Algernon Coolidge, Boston.
William O. Crosby, Boston.
William M. Davis, Cambridge.
Jules Marcou, Cambridge.
William H. Niles, Cambridge.
Nathaniel S. Shaler, Cambridge.
Charles U. Shepard, Amherst.

SECTION II. — 8.

Botany.

William G. Farlow, Cambridge.
George L. Goodale, Cambridge.
Asa Gray, Cambridge.
H. H. Hunnewell, Wellesley.
Charles S. Sargent, Brookline.
Charles J. Sprague, Boston.
Edward Tuckerman, Amherst.
Sereno Watson, Cambridge.

SECTION III. — 22.

Zoölogy and Physiology.

Alex. E. R. Agassiz, Cambridge.
Joel A. Allen, New York.
Robert Amory, Brookline.
Nath. E. Atwood, Provincetown.
James M. Barnard, Boston.
Henry P. Bowditch, Boston.
Edward Burgess, Boston.
John Dean, Waltham.
Walter Faxon, Cambridge.
Hermann A. Hagen, Cambridge.
Charles E. Hamlin, Cambridge.
Alpheus Hyatt, Boston.
Samuel Kneeland, Boston.
Theodore Lyman, Brookline.
Edward L. Mark, Cambridge.
Charles S. Minot, Boston.
Edward S. Morse, Salem.
James J. Putnam, Boston.
Samuel H. Scudder, Cambridge.
D. Humphreys Storer, Boston.
Henry Wheatland, Salem.
James C. White, Boston.

SECTION IV. — 19.

Medicine and Surgery.

Samuel L. Abbot, Boston.
Henry J. Bigelow, Boston.
Henry I. Bowditch, Boston.
Benjamin E. Cotting, Roxbury.
Frank W. Draper, Boston.
Thomas Dwight, Boston.
Robert T. Edes, Boston.
Charles F. Folsom, Boston.
Richard M. Hodges, Boston.
Oliver W. Holmes, Boston.
Alfred Hosmer, Watertown.
Francis Minot, Boston.
John P. Reynolds, Boston.

Wm. L. Richardson,	Boston.
George C. Shattuck,	Boston.
J. Baxter Upham,	Boston.
Charles E. Ware,	Boston.
John C. Warren,	Boston.
Henry W. Williams,	Boston.

CLASS III. — *Moral and Political Sciences.* — 59.

SECTION I. — 14.

Philosophy and Jurisprudence.

James B. Ames,	Cambridge.
Charles S. Bradley,	Providence.
Phillips Brooks,	Boston.
James F. Clarke,	Jamaica Pl.
Charles C. Everett,	Cambridge.
Horace Gray,	Boston.
John C. Gray,	Boston.
Laurens P. Hickock,	Northampton.
Oliver W. Holmes, Jr.,	Boston.
Mark Hopkins,	Williamstown.
C. C. Langdell,	Cambridge.
John Lowell,	Newton.
Henry W. Paine,	Cambridge.
James B. Thayer,	Cambridge.

SECTION II. — 16.

Philology and Archæology.

William S. Appleton,	Boston.
William P. Atkinson,	Boston.
Lucien Carr,	Boston.
Joseph T. Clarke,	Boston.
Henry G. Denny,	Boston.
Epes S. Dixwell,	Cambridge.
William Everett,	Quincy.
William W. Goodwin,	Cambridge.
Ephraim W. Gurney,	Cambridge.
Henry W. Haynes,	Boston.
Bennett H. Nash,	Boston.
Frederick W. Putnam,	Cambridge.
John L. Sibley,	Cambridge.
John W. White,	Cambridge.
Justin Winsor,	Cambridge.
Edward J. Young,	Cambridge.

SECTION III. — 18.

Political Economy and History.

Chas. F. Adams, Jr.,	Quincy.
Henry Adams,	Boston.
Edward Atkinson,	Boston.
John Cummings,	Woburn.
Charles Deane,	Cambridge.
Charles F. Dunbar,	Cambridge.
Samuel Eliot,	Boston.
George E. Ellis,	Boston.
Edwin L. Godkin,	New York.
Edward Everett Hale,	Boston.
Henry P. Kidder,	Boston.
Henry C. Lodge,	Boston.
Augustus Lowell,	Boston.
Francis Parkman,	Boston.
Andrew P. Peabody,	Cambridge.
Henry W. Torrey,	Cambridge.
Francis A. Walker,	Boston.
Robert C. Winthrop,	Boston.

SECTION IV. — 11.

Literature and the Fine Arts.

Charles F. Adams,	Boston.
George S. Boutwell,	Groton.
J. Elliot Cabot,	Brookline.
Francis J. Child,	Cambridge.
Charles G. Loring,	Boston.
James Russell Lowell,	Cambridge.
Charles Eliot Norton,	Cambridge.
Thomas W. Parsons,	Boston.
Charles C. Perkins,	Boston.
H. H. Richardson,	Brookline.
John G. Whittier,	Amesbury.

ASSOCIATE FELLOWS. — 84.

(Number limited to one hundred.)

Class I. — *Mathematical and Physical Sciences.* — 32.

Section I. — 6.

Mathematics.

E. B. Elliott,	Washington, D.C.
William Ferrel,	Washington, D.C.
Thomas Hill,	Portland, Me.
Simon Newcomb,	Washington, D.C.
H. A. Newton,	New Haven, Conn.
James E. Oliver,	Ithaca, N.Y.

Section II. — 12.

Practical Astronomy and Geodesy.

W. H. C. Bartlett,	Yonkers, N.Y.
J. H. C. Coffin,	Washington, D.C.
Wm. H. Emory,	Washington, D.C.
Asaph Hall,	Washington, D.C.
J. E. Hilgard,	Washington, D.C.
George W. Hill,	Nyack, N.Y.
Sam. P. Langley,	Allegheny, Pa.
Elias Loomis,	New Haven, Conn.
Maria Mitchell,	Poughkeepsie, N.Y.
C. H. F. Peters,	Clinton, N.Y.
George M. Searle,	New York.
Chas. A. Young,	Princeton, N.J.

Section III. — 10.

Physics and Chemistry.

F. A. P. Barnard,	New York.
J. Willard Gibbs,	New Haven, Conn.
S. W. Johnson,	New Haven, Conn.
John Le Conte,	Berkeley, Cal.
J. W. Mallet,	Charlottesville, Va.
A. M. Mayer,	Hoboken, N.J.
Albert A. Michelson,	Cleveland, O.
Ogden N. Rood,	New York.
H. A. Rowland,	Baltimore.
L. M. Rutherfurd,	New York.

Section IV. — 4.

Technology and Engineering.

Henry L. Abbot,	New York.
William Sellers,	Philadelphia.
George Talcott,	Albany, N.Y.
W. P. Trowbridge,	New Haven, Conn.

Class II. — *Natural and Physiological Sciences.* — 26.

Section I. — 13.

Geology, Mineralogy, and Physics of the Globe.

Cleveland Abbe,	Washington, D.C.
George J. Brush,	New Haven, Conn.
James D. Dana,	New Haven, Conn.
J. W. Dawson,	Montreal, Canada.
J. C. Fremont,	New York.
F. A. Genth,	Philadelphia.
James Hall,	Albany, N.Y.
F. S. Holmes,	Charleston, S.C.
Clarence King,	Washington, D.C.
Joseph Le Conte,	Berkeley, Cal.
J. Peter Lesley,	Philadelphia.
R. Pumpelly,	Newport, R.I.
Geo. C. Swallow,	Columbia, Mo.

SECTION II. — 2.

Botany.

A. W. Chapman, Apalachicola, Fla.
Leo Lesquereux, Columbus, Ohio.

SECTION III. — 6.

Zoölogy and Physiology.

S. F. Baird, Washington, D.C.
J. C. Dalton, New York.
Joseph Leidy, Philadelphia.
O. C. Marsh, New Haven, Conn.
S. Weir Mitchell, Philadelphia.
A. S. Packard, Providence.

SECTION IV. — 5.

Medicine and Surgery.

Fordyce Barker, New York.
John S. Billings, Washington, D.C.
Jacob M. Da Costa, Philadelphia.
W. A. Hammond, New York.
Alfred Stillé, Philadelphia.

CLASS III. — *Moral and Political Sciences.* — 26.

SECTION I. — 8.

Philosophy and Jurisprudence.

D. R. Goodwin, Philadelphia.
A. G. Haygood, Oxford, Ga.
R. G. Hazard, Peacedale, R.I.
Nathaniel Holmes, Cambridge.
James McCosh, Princeton, N.J.
Charles S. Peirce, New York.
Noah Porter, New Haven, Conn.
Jeremiah Smith, Dover, N.H.

SECTION II. — 7.

Philology and Archæology.

A. N. Arnold, Pawtuxet, R.I.
D. C. Gilman, Baltimore.
A. C. Kendrick, Rochester, N.Y.
E. E. Salisbury, New Haven, Conn.
A. D. White, Ithaca, N.Y.
W. D. Whitney, New Haven, Conn.
T. D. Woolsey, New Haven, Conn.

SECTION III. — 6.

Political Economy and History.

George Bancroft, Washington, D.C.
S. G. Brown, Hanover, N.H.
Henry C. Lea, Philadelphia.
J. H. Trumbull, Hartford, Conn.
M. F. Force, Cincinnati.
W. G. Sumner, New Haven, Conn.

SECTION IV. — 5.

Literature and the Fine Arts.

James B. Angell, Ann Arbor, Mich.
L. P. di Cesnola, New York.
F. E. Church, New York.
R. S. Greenough, Florence.
William W. Story, Rome.

FOREIGN HONORARY MEMBERS.—71.

(Appointed as vacancies occur.)

CLASS I.—*Mathematical and Physical Sciences.*—24.

SECTION I.—6.

Mathematics.

John C. Adams,	Cambridge.
Sir George B. Airy,	Greenwich.
Francesco Brioschi,	Milan.
Arthur Cayley,	Cambridge.
Charles Hermite,	Paris.
J. J. Sylvester,	Oxford.

SECTION II.—5.

Practical Astronomy and Geodesy.

Arthur Auwers,	Berlin.
J. H. W. Döllen,	Pulkowa.
H. A. E. A. Faye,	Paris.
Eduard Schönfeld,	Bonn.
Otto Struve,	Pulkowa.

SECTION III.—10.

Physics and Chemistry.

Adolf Baeyer,	Munich.
Marcellin Berthelot,	Paris.
R. Bunsen,	Heidelberg.
M. E. Chevreul,	Paris.
H. Helmholtz,	Berlin.
A. W. Hofmann,	Berlin.
G. Kirchhoff,	Berlin.
Balfour Stewart,	Manchester.
G. G. Stokes,	Cambridge.
Julius Thomsen,	Copenhagen.

SECTION IV.—3.

Technology and Engineering.

R. Clausius,	Bonn.
F. M. de Lesseps,	Paris.
Sir Wm. Thomson,	Glasgow.

CLASS II.—*Natural and Physiological Sciences.*—26.

SECTION I.—7.

Geology, Mineralogy, and Physics of the Globe.

Heinrich E. Beyrich,	Berlin.
Alfred des Cloizeaux,	Paris.
James Prescott Joule,	Manchester.
C. F. Rammelsberg,	Berlin.
A. C. Ramsay,	London.
Bernhard Studer,	Berne.
Heinrich Wild,	St. Petersburg.

SECTION II.—7.

Botany.

J. G. Agardh,	Lund.
Alphonse de Candolle,	Geneva.
August W. Eichler,	Berlin.
Sir Joseph D. Hooker,	London.
Carl Nägeli,	Munich.
Julius Sachs,	Würzburg.
Marquis de Saporta,	Aix.

SECTION III. — 8.

Zoölogy and Physiology.

Milne Edwards,	Paris.
Thomas H. Huxley,	London.
Albrecht Kölliker,	Würzburg.
Rudolph Leuckart,	Leipsic.
C. F. W. Ludwig,	Leipsic.
Richard Owen,	London.
Louis Pasteur,	Paris.
J. J. S. Steenstrup,	Copenhagen.

SECTION IV. — 4.

Medicine and Surgery.

C. E. Brown-Séquard,	Paris.
F. C. Donders,	Utrecht.
Sir James Paget,	London.
Robert Virchow,	Berlin.

CLASS III. — *Moral and Political Sciences.* — 21.

SECTION I. — 3.

Philosophy and Jurisprudence.

Sir Henry Sumner Maine,	London.
James Martineau,	London.
Sir James F. Stephen,	London.

SECTION II. — 7.

Philology and Archæology.

Georg Curtius,	Leipsic.
Pascual de Gayangos,	Madrid.
Benjamin Jowett,	Oxford.
G. C. C. Maspero,	Cairo.
Max Müller,	Oxford.
H. A. J. Munro,	Cambridge.
Sir H. C. Rawlinson,	London.

SECTION III. — 7.

Political Economy and History.

Ernst Curtius,	Berlin.
W. Ewart Gladstone,	London.
Charles Merivale,	Ely.
Theodor Mommsen,	Berlin.
Von Ranke,	Berlin.
Jules Simon,	Paris.
William Stubbs,	Chester.

SECTION IV. — 4.

Literature and the Fine Arts.

Matthew Arnold,	London.
Jean Léon Gérôme,	Paris.
John Ruskin,	Coniston.
Lord Tennyson,	Isle of Wight.

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